ECOTOURISM AND ITS ECOLOGICAL IMPACT: A STUDY OF TOURIST DEVELOPMENTS IN THE MARA ECOSYSTEM, KENYA

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ABSTRACT

The increased growth of wildlife tourism in Kenya over the last few decades has placed increasing demand and attention for the development and subsequent delivery of sustainable tourism. Today ecotourism ventures are perceived by many as a solution to the negative impacts of "traditional" wildlife tourism and thus a way to achieve ecological sustainability within the industry. To date however, there has been no attempt to qualify and quantify any possible wildlife impacts of ecotourism - the basis of this research, using the Mara Ecosystem as a case study.

Using WildKnowledge© software, this research recorded biotic and abiotic data from wildlife tourism developments of various sizes and assessed their anthropogenic impacts upon key ungulate species in the ecosystem over a three year period. The findings of this aspect of the research indicate that the effects of the tourism industry on wildlife are highly species specific. In particular Buffalo were most affected by differences in tourism seasonal variability (χ^2=5.040, df=1, p=0.025), distance to developments (χ^2=23.341, df=1, p=0.000) and group size (χ^2=7.998, df=1, p=0.005) between the different lodge types. In contrast, waterbuck and eland displayed similar patterns of disturbance irrespective of lodge type or tourism seasonal variability. Using historical species count data spanning a twenty year period, kernel density maps were constructed to demonstrate spatial changes in ungulate density and distribution patterns in relation to tourism growth. The resulting density maps revealed that while the national reserve offered a measure of security to wildlife, many ungulate species still heavily utilised their historical dispersal areas in the community lands. Interestingly, despite the tourism related land use changes demonstrated in the Mara's landscape, some species e.g. eland, displayed an increase in range size - to 450.5km^2 in 2010 from 399.5km^2 in 2005 following the creation of wildlife conservancies in the surrounding ranches.

Constructing site suitability models, the research explored how GIS modelling techniques can be employed to identify suitable locations for tourist accommodation, without compromising the ecological integrity of the wildlife areas where these facilities will be located. Employing two different bed occupancy models (conservancy model; 350 acres/bed and a current model; ; 174 acres/bed, derived from existing facilities), the Mara Ecosystem's ability to accommodate further tourism growth at low ecological cost was demonstrated. Application of the highest suitability criteria to select potential development sites revealed two suitable locations. A further 54 locations were identified as suitable for ecocamps and ecolodges on application of the second highest site selection suitability criteria. Importantly, the models employed clearly demonstrate that the majority of future ecotourism facilities be located outside the National Reserve in the group ranches if they are to have limited wildlife impact, as over-utilisation of any single sections of the ecosystem will lead to resource depletion and localized species loss.

The results presented highlight the need for a more integrative approach to ecotourism provision. The utility of GIS based models to project the impacts of human disturbances on wildlife populations under different tourism scenarios is reinforced by this research. These suitability models are easily modified and can therefore be used under different planning scenarios in other wildlife areas in Kenya and the region. It is therefore hoped, that the results from this study will influence policy direction for tourism planning in wildlife areas for the Mara and other ecosystems, and be used to complement the country's tourism and wildlife bills which are about to be passed into law. This research concludes that although ecotourism plays an important role in environmental conservation, its ecological impacts on wildlife in receiving environments can be significant and should be a primary consideration in deciding upon the efficacy of individual proposals.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis Of Variance
DRSRS	Department of Remote Sensing and Resource Survey
EK	Ecotourism Kenya
EK	Ecotourism Kenya
GIS	Geographical Information System
GPS	Global Positioning System
IBA	Important Bird Area
ILRI	International Livestock Research Institute
ITCZ	Inter Tropical Convergence Zone
IUCN	International Union for Conservation of Nature
KWS	Kenya Wildlife Service
MCDA	Multi Criteria Decision Analysis
NCC	Narok County Council
MMNR	Maasai Mara National Reserve
SDM	Species Distribution Models
SELU	Spatial Ecology and Land Use Unit
TIES	The International Ecotourism Society
UNEP	United Nations Environment Programme
WWF	World Wide Fund for Nature

Chapter 1

INTRODUCTION

1.1 Introduction

Over the past few decades, global tourism has experienced continuous growth to become one of the world's fastest growing economic sectors generating €693 billion in annual export earnings. The World Tourism Organization reports that between 1950 and 2010, international tourism arrivals increased at an annual rate of 6.2%, growing from 25 million to 940 million tourists (World Tourism Organization, 2011). A shift in interest has also been witnessed to new tourism destinations in developing countries, especially those rich in biodiversity such as Central America, Southern and Eastern Africa and South and East Asia (Roe *et al.*, 1997). These countries offer the most well-known and popular wildlife-watching destinations (Valentine and Birtles, 2004), making wildlife their major tourism attraction (Roe *et al.*, 1997). These destinations witnessed a 47% growth in 2010 in international tourist arrivals up from 32% in 1990 (Roe *et al.*, 1997, World Tourism Organization, 2011). Kenya, like most developing countries in the region relies on tourism as a key economic activity, making it the country's third largest foreign exchange earner after tea and horticulture (Ikiara and Okech, 2002, Ministry of Tourism and Wildlife, 2006, Ministry of Tourism and Wildlife, 2008).

1.2 Tourism in Kenya

Kenya lies along the East coast of Africa covering an area of 582,350 sq. kilometres with an estimated population of 38 million (Kenya National Bureau of Statistics, 2010a). It is a popular tourism destination attracting about 6% of Africa's total overseas visitor numbers. The country's tourism industry is mainly based around nature with its wildlife resources distributed in over sixty locations including national parks, game reserves and sanctuaries covering close to 8% of the country (Western *et al.*, 2009, United Nations, 2011, Ondicho, 2000).

Wildlife tourism in Kenya dates back to the pre-independence era and can be traced as far back as the early 1930's when overseas visitors and explorers started arriving in Kenya mainly for big-game hunting, locally referred to as 'Safaris'. At that time, the country's tourism infrastructure was relatively well developed but limited. After independence in 1963, the government realised the potential of the tourism industry to aid economic growth and took steps to upgrade the existing infrastructure, developing and investing in additional facilities by encouraging both local and foreign businesses to invest in the country's tourism and hospitality industries (United Nations, 2011). When big game hunting, which encouraged the upper segment of the market, was banned in Kenya in 1977, the focus shifted to target the middle income segment of the market. Typically this involved inclusive packages with tourists visiting the country in large numbers, making Kenya a popular mass tourism destination. A growing awareness of the environmental impacts of tourism together with the increased demands from tourists for new experiences has raised awareness on the need for integration of environmental conservation with economic development policies, which has consequently led to an interest in sustainable alternatives to mass tourism (Hunter and Green, 1995).

The steady rise of tourists arriving in Kenya over the past ten years (Ministry of Tourism and Wildlife, 2011) has driven the growth of wildlife based tourism in the country leading to increased developments within its parks and reserves. However, the associated physical infrastructure consisting of buildings, roads, airstrip and game proof barriers which serve the tourism industry also contribute to environmental degradation in these areas (United Nations, 2011). This has resulted in special attention now being directed to trying to understand tourism's impacts on receiving environments.

1.3 Environmental impacts of tourism

It has long been acknowledged that human activities play a major role in the loss of native species and habitats, with recreational activities including wildlife tourism contributing to this loss. The United Nations Environment Programme (UNEP) and World Trade Organisation highlight the environmental impacts of tourism to include impacts on soil, water resources, biodiversity, landscape and cultural environments (United Nations, 2011, World Tourism Organization, 2011). However, little is known about the direct positive and negative impacts on the wildlife on which it depends (De Leeuw *et al.*, 2002). According to Karanja (2002), the immediate, long term and cumulative impacts of tourism on biodiversity are not very obvious due to the intrinsic complexities of the ecological systems in which they occur. Consequently, even when an impact from tourism is successfully quantified, further difficulties may arise in determining if that impact is biologically important in the long-term.

The ecological significance of wildlife tourism impacts differ considerably between different ecosystems, and while localized and easily measureable impacts have been studied in detail, the hidden and hard to measure impacts have little data in existence with which to create predictive models across a broad range of ecosystems (Buckley, 2004a). Extensive theoretical literature exists on ecotourism's perceived goals and the potential mechanisms with which to achieve them (Weaver and Lawton, 2007), but little of this literature analyses individual commercial ecotourism products and their environmental impacts (Buckley, 2009). It is vital that tourism's impacts on wildlife be appraised and presented against an ecological background, where affected areas are assessed using existing baseline data (species life history parameters, habitat requirements, natural movements and social behaviour) overlaid by their responses to the industry's activities (Rodger and Moore, 2004). In-depth studies using scientific methodology are needed to assess and consequently mitigate the negative ecological impacts of wildlife tourism. To this end, this research seeks to incorporate an empirical approach to assess the impacts of tourist developments to wildlife, investigating how and the extent to which they affect distribution patterns and densities of key ungulate species in the Mara Ecosystem, Kenya.

1.4 Aims and Objectives

This study is structured around two major aims:

1. To examine the anthropogenic impacts of different wildlife tourism developments (eco-facilities and traditional lodges) on key ungulate species in the Mara Ecosystem.

2. To develop a GIS model to identify optimum locations for proposed tourist developments highlighting any likely impacts to key species in wildlife areas.

In order to realize the above aims, the following objectives have been identified:

a. Examine the interactions between ungulate species and tourist developments (eco-facilities and traditional facilities) through analysis of recorded environmental and physical variables.
b. Determine through statistical tests, any significant differences in ungulate response to eco-facilities and traditional lodges.
c. Model temporal changes in species abundance and distribution in relation to tourism growth by analysing species spatial distribution patterns over a twenty year period (1990 – 2010).
d. Create a GIS based suitability / optimisation model to identify suitable locations for new developments.
e. Use GIS to project likely impact scenarios of proposed tourist developments to ungulate species in the study area.
f. Propose a suitable strategy to be used by decision makers to indicate levels of acceptability of any proposed developments; and influence policy direction in relation to tourism planning in wildlife areas.

Chapter 2

LITERATURE REVIEW

2.1 Wildlife tourism

Wildlife tourism, based on encounters with non-domesticated animals in their natural environments or in captivity, is one of the industry's fastest growing sectors. It encompasses a range of activities which involve elements of adventure including bird watching, wildlife viewing, photographic and walking safaris (Rodger and Moore, 2004, Roe *et al.*, 1997, Newsome *et al.*, 2004, Higham and Lusseau, 2007). Tourism represents 83% worldwide export and acts as the main foreign currency earner for 38% of the world's countries (Christ *et al.*, 2003).

Tourism growth, especially in developing countries, has raised expectations for improved revenues for wildlife parks and higher investments in conservation. However, the park systems in these countries have failed to invest in the necessary levels for capacity building needed to heighten growth, making tourism a threat to biodiversity rather than a benefit (Drumm, 2008). It has been argued that tourism's impacts on wildlife in many cases may be less significant than those associated with other industries like agriculture. Major concern has however been expressed about its effects on wildlife survival and reproduction especially amongst national park populations (Newsome *et al.*, 2004). Tourism's impact on wildlife and their habitats as well as the industry's sustainability are now in question, but as is the case with many other sectors, the practical and conceptual elements of sustainable wildlife tourism are still evolving.

In the areas it occurs, the rapid growth of wildlife tourism has triggered a variety of socio-economic, cultural and ecological changes causing untold damage to some of the most endangered ecological systems (Blangy and Mehta, 2006), presenting tourism managers and planners with the challenge of controlling visitor numbers without disturbing those ecosystems and their wildlife (Watkin *et al.*, 2002). Some of the ways that the wildlife tourism industry has detracted from conservation has been through its environmental impacts especially in protected areas from associated infrastructure including roads, lodges, airstrips, alternative electricity supplies and waste management systems (Roe *et al.*, 1997). These often expose wildlife to a range of unusual stimuli which may in time influence their responses (Green and Giese, 2004) and have widespread and profound ecological impacts (Cole, 2004, Walpole *et al.*, 2003).

Making the resource base more resilient is a first step to achieving sustainability within the sector. Hunter and Green (1995) suggest that tourism ultimately relies on the maintenance of environmental resources for its continued wellbeing. Because of the short term research common within tourism studies, scientific monitoring and assessment of the long term nature of its potential impacts have been rendered difficult due to consistent neglect. One of the difficulties faced in trying to avert the environmental and ecological impacts of any form of tourism is the ability of the visited area to absorb tourists without intruding on the visitor's experience (Kenya Wildlife Service, 1996).

The practicalities of monitoring tourism's ecological impacts remain problematic for many agencies despite being widely recognized. Difficulties exist in assessing the impact of human activities on wildlife populations while adhering to the strict methodologies necessary to objectively assess any associated impacts (Buckley, 2003). Most existing studies on tourism's impacts on wildlife have failed to capture the complex interrelationships between the different variables that may be present and have instead considered single interactions such as impact on feeding patterns in individual species (Roe *et al.*, 1997). In addition, few studies have been commissioned to understand the long-term impacts associated with human disturbance to various wildlife species (Higham and Lusseau, 2007) because of the challenges that exist in carrying out research into impacts which are difficult to identify and measure (Newsome *et al.*, 2004).

2.2 Sustainable tourism and ecotourism

Sustainable development is described in The Brundtland report as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'(United Nations, 1987). Shaw and Williams (2002) and Christ *et al.* (2003) note that the ideology of sustainability within tourism has had a significant impact in the emergence of sustainable tourism as a more responsible form of mass tourism. Sustainable wildlife tourism aims to meet the needs of both the tourist and the host region while maintaining cultural integrity, essential ecological processes, biological diversity and life support systems (Newsome *et al.*, 2004).

Ecotourism has been fronted as a potential tool to improve tourism's sustainability by reconciling the conflict that exists between development and conservation through modification of human social behaviour with regard to environmental conservation (Southgate, 2006). It has been described as:

i. "travelling to relatively undisturbed or uncontaminated natural areas with the specific objective of studying, admiring, and enjoying the scenery and its wild plants and animals, as well as many existing cultural manifestations found in these areas"(Ceballos-Lascuran, 1996)
ii. "a set of practices and principles challenging conventional tourism by focusing on tourist activities and their environmental and social impacts" (Christ *et al.*, 2003);
iii. "Responsible travel to natural areas that conserves the environment and sustains the well-being of local people" (TIES., 2011);
iv. "ecologically sustainable tourism that fosters environmental and cultural understanding and appreciation" (Rotherham *et al.*, 2000).

Ecotourism aims to incorporate minimal-impact environmental practices, reversing the environmental degradation and community exploitation caused by conventional tourism (Buckley, 2004a). It does this through its preference for the small scale, its utilisation of locally available materials and a fundamental interest in waste minimisation and recycling (Southgate, 2006). While its negative impacts are said to be less than those of traditional tourism, eco-tourism's impacts can be described in terms of the damage it inflicts both intentionally and unintentionally (Isaacs, 2000).

The reality of ecotourism is that it can both sustain and degrade ecosystems (Vanasselt, 2000) although in developing countries where conservation frameworks are often less effective, ecotourism's impacts are probably positive because impacts from other sectors are seen to cause greater risks (Buckley, 2004b). To ensure ecotourism's sensitivity to fragile ecosystems, greater attention should be paid to destination planning, resource management and the quality and price of the product. However, few examples demonstrate that ecotourism destinations have been planned with these in mind with even carefully managed ecosystems such as the Galapagos Islands showing signs of degradation in recent years (Vanasselt, 2000). An increase in visitor numbers to these Islands has resulted in eroded tourist trails, disturbance to local plant and animal species and a decline in the general tourism experience (Brandon, 1996, Stem *et al.*, 2003, Roe *et al.*, 1997).

In order to capture a portion of the ecotourism market, countries and wildlife parks need to carefully monitor impacts resulting from increased visitor numbers and their activities, taking steps to overcome the challenges facing this industry. Even though it has been noted to have many mechanisms for potential positive contributions to conservation, ecotourism's practical quantitative contribution to date has been small (Buckley, 2004b). Sindiga (1999) observes that in some cases, ecotourism is seen more as a business propaganda tool to attract clients rather than adhere to the principles upon which it is based. While on one level it offers opportunities for economic diversification, it can also exacerbate existing resource management conflicts, for instance the development of ecotourism facilities in virgin areas to provide exclusivity to tourists. Ecotourism, if well practised can protect and enhance the environment, respect local culture and provide benefits to host communities and at the same be educational and enjoyable for the tourist (Blangy and Mehta, 2006).

2.3 Ecological impacts of ecotourism

Sustainable wildlife tourism management requires in-depth understanding of critical wildlife behaviours and the identification and protection of habitats where these behaviours take place. It is recognized that in the majority of cases, engagements between wildlife and tourists take place where the wildlife are predictably located and concentrated. These interactions mostly occur where critical behaviours such as feeding take place and where wildlife populations are most likely to tolerate, and perhaps accommodate otherwise unacceptable levels of stress associated with the presence of tourists (Newsome *et al.*, 2002, Newsome *et al.*, 2004, Olindo, 1997). Primates for instance, feel safer in areas with larger trees while hippopotami can be approached more easily when in water (Newsome *et al.*, 2004, Roe *et al.*, 1997). This has raised fears that wildlife will eventually avoid such areas and move to relatively undisturbed locations. While some habitats appear to be rarely utilised by wildlife, they may provide critical resources during lean periods such as during droughts

(Green and Giese, 2004). It is important, to take into account seasonal factors and food supply when measuring levels of disturbance to wildlife.

The clearing and modification of habitats for ecotourism accommodation and supporting infrastructure can result in the reduction or disappearance of key resources essential for wildlife feeding, breeding and safety (Newsome *et al.*, 2004). The presence of a tourist development can result in avoidance or attraction by wildlife species depending on its scale and activities in relation to the environment and the wildlife species involved (Newsome *et al.*, 2004, Olindo, 1997). Male reindeer (*Rangifer tarandus tarandus)* in Rondane National Park, Norway were observed to be more tolerant of tourist developments than females who tended to avoid resorts by a 10km zone; this has been seen as potentially impacting on the productivity of the herd because of reduced available habitat and forage intake during the winter season (Nellemann *et al.*, 2000).

Wildlife tolerance levels vary with age, breeding season, time of year and habitat type. Animals are generally more sensitive to disturbance and potentially more aggressive when caring for young or while feeding. Elephants and bears produce dramatic and violent responses to disturbance when caring for young offspring (Newsome *et al.*, 2002) while cheetahs have been observed to change their feeding patterns as a result of vehicle disruption during their hunting and feeding sessions which could have serious implications for food intake and, consequently the long-term survival of individuals and their young (Roe *et al.*, 1997). Wild boar (*Sus scrofa*) in the Wanda Mountains of Heilongjiang Province, China avoid coniferous forests, their habitat of preference, and areas of human settlements due to the presence of local people collecting conifer seeds in the forests (Zhou and Zhang, 2011), denying them a chance to feed.

Buckley (2004a) suggests that disturbance does not need not be dramatic to produce significant ecological consequences, and because historical research on tourism's impacts concentrated mainly on habitat destruction, hunting and poaching, ecotourism's impact was viewed as negligible. Where recorded, its impact on wildlife has been shown at times to be species-specific, with some animals increasing in density as they become habituated to human presence, some withdrawing causing a decrease in numbers, and others remaining unaffected (Hidinger, 1999). Short term studies on nesting Northern Royal Albatross (*Diomedea sanfordi)* populations in

Taiaroa, New Zealand show no negative short term impact from tourists watching them, but longer-term data have revealed significant changes in the breeding colony (Green and Giese, 2004). Similarly, behavioural studies on three species of Galapagos Islands boobies; Red-Footed Booby *(Sula sula)*, Blue-Footed Booby *(Sula neboxuii)* and Masked Booby *(Sula dactylatra)*, showed subtle changes which were not obviously present when tourists were present, but with repeated passage by tourist groups, the birds faced disturbance for much of their day (Roe *et al.*, 1997).

Ecotourism has been recorded as also causing long-term impacts to the flora and fauna in ecosystems such as the Galapagos where Waved Albatrosses *(Phoebastria irrorata)* at Punta Suarez have changed the locations of their nesting sites away from tourist sites (Roe *et al.*, 1997). Human disturbance has been found to elevate glucocorticoid concentrations in wild animals leading to high stress levels and resulting in complications including reproductive failure and neuron death (Romero and Wikelski, 2002). A study in an Ecuadorian Wildlife Reserve on eco-tourists and their impacts on the reproductive success of hoatzins (*Opisthocomus hoazin*) established that hatching success was higher in undisturbed nests compared to those exposed to tourist visitation. Juvenile hoatzin were noted to have a higher response to stress while younger chicks had a lower survival rate which was linked to increased vigilance, high stress levels and energy expenditure, displacement from nesting trees and reduced parental attention (Newsome *et al.*, 2004, Franklin, 2010). Likewise, Galapagos Sea-Lions (*Zalophus wollebaeki)* showed increased aggression and nervousness as a consequence of stress. Balloon safaris which are a regular feature of wildlife tourism in several protected areas appear to cause considerable distress to particular species, notably African buffalo *(Synecarus caffer)* and lion *(Panthera leo)* (Roe *et al.*, 1997).

Ecotourism's success has the potential to lead to its demise according to Stem *et al.*(2003), who explain that the more successful an ecotourism initiative, the more it draws interest and a correspondingly higher number of tourists, thereby increasing negative impacts such as waste solid generation and habitat disturbance. Its main premise is the viewing of wildlife in its natural environment. Great care has to be taken to make sure unsustainable growth of the industry does not damage the receiving environment. Ecotourism involving watching whales and dolphins in coastal communities are becoming increasing popular (Lusseau, 2003) and have seen a dramatic rise especially in South Africa, Australia and North America during the last ten years (Newsome *et al.*, 2002). The rise of tourist numbers from 9 million in 1998 up from 4 million in 1991 in Doubtful Sound, Fiordland, New Zealand, has led to concerns on the effects of tourism activities to the behavioural budget of small cetaceans. A study on the impact of boat based activities on bottlenose dolphins *(Tursiops truncates)*, for example, indicated that as a result of increased interactions with tour boats, the dolphins displayed uncommon natural responses such as unusual surfacing behaviour, avoidance, alteration of swimming speeds and decreases in socialization and resting durations (Lusseau, 2003, Green and Giese, 2004).

Not all interactions between wildlife and the tourism industry have been observed as negative. Some animals react positively to human presence (Newsome *et al.*, 2002) and display lower signs of stress in tourist-visited areas. In order to measure stress responses of Galapagos marine iguanas *(Amblyrhynchus cristatus)* to tourism-related disturbance, levels of corticosterone, the stress hormone, from two different populations were measured. No distinguishable differences were recorded between animals at tourist-exposed versus undisturbed sites indicating that tourism does not chronically stress the iguanas. This study indicated that the iguanas were habituated to the presence of tourists in the Galapagos Islands, a popular eco-tourism destination, with strict controls on annual visitor numbers and restrictions keeping tourists to well-defined viewing trails (Romero and Wikelski, 2002). In Australia, Red-necked wallabies *(Macropus rufogriseus)* will flee at the presence of humans, but those at picnic sites or golf courses have a higher tolerance to approach by humans and in some cases may seek out people for food offerings (Newsome *et al.*, 2002); female brown bears *(Ursus arctos)* in British Columbia prefer being in close proximity to visitors to ward off attacks by aggressive males while Cape glossy starlings *(Lamprotornis nitens)* were attracted to visitors at dining and picnic areas in Kruger National Park, South Africa where there was easy access to food (Newsome *et al.*, 2002).

2.4 Ecotourism planning

Given the range of potential ecotourism impacts and possible wildlife responses, it is essential that good scientific research is available to inform wildlife managers of these impacts. Rodger and Moore (2004) argue that wildlife tourism, if well managed, can deliver the economic benefits, community involvement and support and preservation of the environment that are requirements for a sustainable form of tourism development, such as ecotourism, in relatively undeveloped regions.

Feick and Brent-Hall (2000) note that land use planning and activities related to tourism cannot be adequately carried out in isolation to their dependencies on other human activities, natural processes and their competition for physical, human and economic resources. As tourism expands into new natural areas, there is great need for mechanisms safeguarding these ecosystems to be in place. In their article on tourism in small island states, they assert that without careful management and planning, tourism can be an unsustainable alternative to other land uses and has the potential to generate conflict and exhaust the long term viability of tourism.

The combined impacts of tourism accommodation, supporting infrastructure, levels of resource consumption, location and intensity of activities result in larger and significant impact situations. During lodge construction, erosion or vegetation damage often occur leading to loss of habitats which support various species and in the creation of a complex node of corridors which act as disturbance sources. This is particularly so if the development is situated entirely in a natural setting or in areas where the wildlife area exists as a patch within a matrix of other land uses as is the case with the Mara Ecosystem. The establishment of wildlife-tourism businesses and designation of sanctuaries relies on available information on how best to maximize locations with high wildlife populations (Sindiga, 1999, Christ *et al.*, 2003, Franklin, 2010). Any management strategies aimed at minimizing ecological impacts in wildlife areas should therefore take into account the type of tourism development, wildlife species present and the ecology of the site where the interactions will take place rather than looking to solely provide visitor viewing satisfaction (Higham and Lusseau, 2007).

It is clear that the extent and significance of any cumulative ecotourism impacts depend on the sensitivity of the receiving environment, the scale at which the sources of the impact are developed and applied as well as the effectiveness of prevailing management systems. The belief that the larger a natural area, the more likely it is to 'absorb' various impacts has led to the creation and management of wildlife conservancies (Newsome *et al.*, 2004). However, if this is not controlled, small scale operations in environmentally sensitive locations may eventually turn into larger more destructive operations in a bid to meet the growing demands of the industry (Roe *et al.*, 1997). Care must therefore be taken and measures put in place when setting up tourist developments to ensure that the carrying capacities of fragile ecosystems are not exceeded.

2.4.1 Using GIS in ecotourism planning

A Geographical Information System (GIS) is described as an integrated technology used to visualise and analyse geographically referenced information. It contains a powerful set of tools that can efficiently collect store, retrieve, manipulate and display spatial data about a particular feature whilst handling several different datasets (Olafsdottir and Runnstrom, 2009, Khaemba and Stein, 2000). Although it is a complex process involving large datasets, species geographical extents and data quality, this practice has grown in recent years.

GIS is recognized as a valuable tool for managing, analysing and displaying large volumes of data pertinent to planning activities (Feick and Brent-Hall, 2000) with the ability to handle multiple spatial criteria and provide tools to aid in the allocation of resources between conflicting demands, consequently aiding planning decision-makers decisions (Olafsdottir and Runnstrom, 2009). An important aspect of conservation and land use planning involves the mapping of areas of species richness and distribution (Oindo *et al.*, 2003). Maps help identify areas of special biodiversity importance, where conservation resources should be focused and species 'hot spots' which may be locations of species richness where species assemblages of particular interest occur.

Despite its increased use in environmental planning and management, the application of GIS to tourism planning is still limited. It has been restricted by lack of long-term, comprehensive and systematic data on issues relevant to wildlife tourism planning such as the interactions between wildlife and associated developments (Olafsdottir and Runnstrom, 2009, Feick and Brent-Hall, 2000). However, Khaemba and Stein (2000) note that wildlife surveys can now be carried out using sampling procedures optimised through the consideration of landscape features and environmental factors stored in a GIS. They further add that it has aided in the simultaneous study of relationships between animal population dynamics and environmental factors, and can be used to calculate wildlife densities, assess habitat suitability for wildlife populations and assess tourism's potential impact on wildlife and land.

Predictive GIS modelling is an important tool that can be used to assess the impact of accelerated land use and other environmental change on species distribution (Guisan and Zimmermann, 2000), with the additional capability of assessing suitability of specific locations earmarked for developments, identifying conflicting interests and modelling relationships between different variables in that location.

2.4.2 Species Distribution Modelling

The rise of powerful statistical techniques and GIS tools has seen an increase in the development of ecological models which can statistically relate the geographical distribution of species to their present environment (Guisan and Zimmermann, 2000). It is becoming increasingly important to map and model species distribution to aid in management and for decision-support purposes, for instance areas identified as potential distribution areas can be used to locate suitable sites for reintroduction programs and fauna corridors (Chefaoui *et al.*, 2005).

Early GIS-based approaches to land use suitability analysis employed overlay techniques where data was mapped on natural and man-made environmental attributes of a study area. This information was presented on individual, transparent maps using light to dark shading to represent high suitability to low suitability areas. The individual transparent maps were then superimposed over each other to construct overall suitability maps for each land use (Malczewski, 2004). Using maps of preferred habitats or combinations of environmental conditions, it is possible to estimate species distribution. This involves mapping distribution of habitat types where the species has been previously recorded and selecting related environmental variables which may then be reclassified into suitability scores and combined to generate a habitat suitability surface (Gaston and Fuller, 2009) (See Figure 2.1 below). Stockwell and Peterson (2002) note that species distribution modelling is essential to ensuring consistency, while reducing time and costs of large-scale biodiversity studies.

Species distribution modelling is an important and well-established tool for conservation planning and resource management using GIS (Vaz *et al.*, 2007). Franklin (2009) describes it as "using statistical and related methods with mapped biological and environmental data in order to model, or in some cases, spatially interpolate species distributions, and other bio-spatial variables of interests, over large spatial extents". Species distribution models (SDMs) are described by Guisan and Zimmerman (2000) as "empirical models relating field observations to environmental predictor variables, based on statistically or theoretically derived response surfaces." It is also referred to as environmental, bioclimatic, or species niche modelling, habitat suitability modelling and as predictive habitat distribution models. It has been used as a tool to identity suitable habitats for species and to understand the relationships between animal population dynamics and environmental variables (Khaemba and Stein, 2000) and has become an important tool for estimating habitat suitability within a wide range of biodiversity management studies (Skova *et al.*, 2007).

SDM has been used to identify potential habitat for jaguar *(Panthera onca)* in the south western United States using datasets from historic sightings, (Hatten *et al.*, 2005); to examine potential impacts of a proposed forest management plant in South Carolina on the population dynamics of Bachman's sparrow *(Peucaea aestivalis)* (Liu *et al.*, 1995); to study the relationship between distribution of female grizzly bears *(Ursus arctos horribilis)*, habitat type and occurrence of roads in Montana (Mace *et al.*, 1996); to predict the location of buzzard *(Buteo buteo)* nests in Argyll, Scotland using vegetation and topographical data (Austin *et al.*, 1996); to predict and produce distribution maps of potential habitat ranges of several fish species by incorporating broad landscape variables into a GIS (Argent *et al.*, 2003); to describe the distribution of three kangaroo species; eastern grey kangaroo *(Macropus giganteus)*, western grey kangaroo *(M. fuliginosus)* and red kangaroo *(M. rufus)*, in Australia against climatic parameters (Walker, 1990); to identify suitable tiger (*Panthera tigris tigris*) habitat areas in Chandoli National Park, India using data from topographic maps in a GIS framework (Imam *et al.*, 2009); to identify potential habitat for the eastern spadefoot toad *(Scaphiopus holbrookii)* in eastern Connecticut using selection criteria from known spadefoot toad sites in other states (Moran and Button, 2011) and; to predict areas of favourable gray wolf *(Canis lupus)* habitat in a newly colonised region in the upper Midwest, United States (Mladenoff *et al.*, 1999).

SDMs requires the incorporation of potential explanatory variables, many of which can be obtained from digital maps e.g. habitat types, rivers, roads, human settlements and altitude as well as data collected during ground surveys such as animal numbers, behaviour and signs of human impact. The conceptual model (Figure 2.1) shows the links in species distribution modelling which are frequently made with species location data and environmental variables to produce a distribution map of species occurrence.

Figure 2.1 Diagram showing components of species distribution modelling (Franklin, 2009)

2.4.3 Species distribution modelling in the Mara Ecosystem

Knowing the geographical distribution of species is necessary for biodiversity conservation and management, however, detailed species distribution data are not readily available for most regions and most taxa. As a result, the use of statistical models is becoming increasingly important as a means for estimating patterns of species occurrence and distribution and as an important tool in informing conservation strategies (Tsoar *et al.*, 2007, Loe *et al.*, 2011, Pearce and Ferrier, 2000).

Populations of many wild ungulate species in Africa are in decline mainly as a result of land use changes and other human activities. Over the last 30 years, populations of almost all large wildlife species in the Mara Ecosystem have reduced by more than two-thirds and are now estimated to be only one-third or less of their former abundance both in the Maasai Mara National Reserve and adjoining ranches (Ogutu *et al.*, 2011, Homewood *et al.*, 2001). Medium brown antelopes have declined by 72% while small brown antelopes have declined by 49%. In individual species, the decline ranges from 52% in Grant's gazelle (*Gazella granti*), 88% in warthog (*Phacochoerus africanus*), 60% in eland (*Taurotragus oryx*) and 73-88% in buffalo (*Syncerus caffer*), giraffe (*Giraffa camelopardalis*) and kongoni (*Alcelaphus buselaphus*) (Ottichilo *et al.*, 2000, Homewood *et al.*, 2001).

In order to understand ungulate dynamics in savannah ecosystems, SDMs have been used to; model the potential impact of climate change on wildebeest (*Connochaetes taurinus*) migratory paths in the Serengeti-Mara Ecosystem, the relationship between rainfall patterns and vegetation cover was characterized in a GIS and using known wildebeest habitat preference, incorporated into a model to predict routes the animals should take (Musiega *et al.*, 2006); predict the spatial distribution of Thompson's gazelle (*Gazella rufifrons*) in Serengeti National Park using field data on food abundance and quality, combined with experimentally derived measures of nutritional value (Fryxell *et al.*, 2004) and; to predict suitability of habitat for large grazing ungulates on Malilangwe Estate wildlife reserve, Zimbabwe taking into account influences of surface water, fire and veld structure (Lochran and Bigalke, 2006).

This study focused on eleven non-migratory ungulate species (Buffalo, Eland, Giraffe, Grants gazelle, Impala, Kongoni, Thompsons gazelle, Topi, Warthog, Waterbuck and Zebra) and elephant (Table 4.1). These species have been mentioned in previous studies as affected by land use changes and human activities in the Mara Ecosystem (Lamprey and Reid, 2004a, Western *et al.*, 2009, Homewood *et al.*, 2001, Ogutu *et al.*, 2011, Ogutu *et al.*, 2009, Ottichilo *et al.*, 2000, Thompson and Homewood, 2002). They are regularlycounted by The Department of Resource Surveys and Remote Sensing (DRSRS) in their annual wildlife counts of the Mara (DRSRS, 2010) and have long term data sets available.

This study has used GIS to model temporal changes in ungulate abundance and distribution over a twenty year period in order to understand the interaction between these species and tourism development in the Mara Ecosystem. A major outcome of this study has been the construction of algorithms in a Geographical Information System (GIS) to model optimal locations and predict likely impacts to the selected wildlife species of any development proposals.

Chapter 3

BACKGROUND

3.1 Introduction

This research investigated the anthropogenic impacts of different wildlife tourism developments (eco-facilities and traditional lodges) upon key ungulate species in the Mara ecosystem taking into account changes in these species' distribution. Attention focused on analysing the spatial and temporal relationship of twelve ungulate species in relation to selected environmental variables during four survey seasons between August 2009 and April 2011 which comprised of two low tourism seasons (February to April) and two high seasons (August to October). Through statistical and geo-statistical analyses, this study further examined the relationship between changes in species distribution patterns and densities and the increasing development of tourist facilities in the Mara Ecosystem. Using GIS techniques, a predictive model using algorithms was constructed to identify potential location for proposed tourist developments highlighting any likely impacts to key species in wildlife areas. Detailed methodologies of each of these areas are included within Chapters Four, Five and Six.

3.2 Study Area

This study focuses on the Mara Ecosystem (hereafter referred to as 'The Mara') which lies between 0°45' and 2°00' S and 34°45' and 36°00' E at an altitude of 1617 meters above sea level in south western Kenya (Ogutu *et al.*, 2010). The Mara comprises the northern part of the greater Serengeti-Mara Ecosystem (Figure 3.1) which covers 30 000 km^2(Norton-Griffiths, 2007) and extends across Southern Kenya and Northern Tanzania encompassing the seasonal movements of the migratory wildebeest and includes the Serengeti National Park, Maswa, Grumeti and Ikorongo Game Reserves and Ngorongoro Conservation Area in Tanzania (Thompson *et al.*, 2009). The Kenyan section of this ecosystem (Figure 3.1) covers 6 650 km^2 and includes the 1 510 km^2 Maasai Mara National Reserve (MMNR). The rangelands adjacent to the MMNR comprise the former group ranches of Koiyaki, Ol Kinyei, Lemek, Maji Moto and Siana as well as private land which makes up the Olchoro Oiroua Wildlife Association area

(Thompson *et al.*, 2009) act as wildlife dispersal areas (Khaemba and Stein, 2000, Walpole *et al.*, 2004), supporting higher wildlife densities than the MMNR at certain times of the year (Ottichilo *et al.*, 2000). The Mara is bordered to the west by the Mara River and the Siria escarpment, which separates the MMNR from the Trans Mara Plateau. It is bounded by the Loita Plateau on the east and by the Kenya-Tanzania border on the southwest (Thompson *et al.*, 2009).

Figure 3.1 Map of the Mara Serengeti Ecosystem showing location of the Mara Ecosystem Source: (Homewood *et al.*, 2001)

3.2.1 Climate

Rainfall in the Mara is bimodal and partly related to the inter-tropical convergence zone (ITCZ) (Serneels *et al.*, 2001), with local variations in topography also playing a major role in the distribution patterns (Ojwang' *et al.*, 2006). The short rains occur during November-December, followed by long rains from March to June (Thompson *et al.*, 2009, Ogutu *et al.*, 2011). There is a rainfall gradient from 600 mm/year in the dry south eastern plains to 1,200 mm/year in the wet north western highlands (Ojwang' *et al.*, 2006, Thompson *et al.*, 2009) and a sharp increase in rainfall with altitude in the Loita Hills and the Siria Escarpment. The Loita Plains and part of the Siana Plains which lie in the rain shadow have a mean rainfall of ~400mm (Thompson *et al.*, 2009, Serneels *et al.*, 2001). Mean monthly temperatures range between 14.7°C and 30°C with annual averages of 18°C (Waithaka, 2004).

The Mara's major rivers (Figure 3.1) are the permanent Talek, Mara and Sand rivers which flow through the reserve and trisect it (Oindo *et al.*, 2003, BirdLife International, 2010) and provide a permanent water source along with many seasonal rivers and streams which are also utilised for domestic use, but mostly dry up in the dry season (Ogutu *et al.*, 2010). Seasonal water availability influences the Mara's ecology and is the key factor determining migration patterns, distribution and abundance of both wildlife and livestock populations (Waithaka, 2004). During the dry season, both wildlife and livestock can be found concentrated around rivers and other permanent water sources but disperse into the outlying plains during the wet season to utilise the abundant forage that is only available during this time (Waithaka, 2004, Ogutu *et al.*, 2010).

3.2.2 Ecology of the Mara Ecosystem

A 2003 report by the International Livestock Research Institute (ILRI) described the Serengeti - Mara Ecosystem as supporting the most diverse migration of grazing mammals on Earth. The Mara, covering a quarter of the ecosystem's total area, is crucial to the Mara-Serengeti's survival, acting as the main foliage source for migrating wildlife in the dry season (Reid *et al.*, 2003). The Mara Ecosystem is home to a wide range of wildlife species, supporting the greatest densities of both wild and domestic herbivores in Kenya(Ogutu *et al.*, 2011), with an estimated herbivore density of nearly 240/km^2 and a biomass of just under 30 tonnes /km^2 (BirdLife International, 2010).

It is famous for its concentration of migratory herbivores, providing dry season range for close to 1.5 million migratory wildebeest (*Connochaetes taurinus*), a hundred thousand zebra (*Equus burchelli*) and several associated grazers, browsers and predators (Ojwang' *et al.*, 2006, Ogutu *et al.*, 2011). The Mara also hosts the 'big five' which are a major tourist attraction; Cape buffalo (*Syncerus caffer*), elephant (*Loxodonta africana*), leopard (*Panthera pardus*), lion (*Panthera leo*) and black rhinoceros (*Diceros bicornis* (Walpole *et al.*, 2003). The Mara has been named as the only region in Kenya that supports an ecologically viable lion population and one of the only remaining indigenous black rhino populations. BirdLife International (2010) classifies it as an Important Bird Area (Fung and Wong) hosting over 500 bird species, including 53 birds of prey.

Common vegetation types (Figure 3.2) in the Mara ecosystem include *Themeda triandra, Pennisetum* spp, *Aristida* spp and *Sporobolus* spp in the open grassland while the low-lying areas support a diverse community of taller grass species such as *Rhus natalensis*. The ecosystem also supports dense thickets of *Cordia ovalis, Croton dichogamus* and *Euclea* spp with the riverine forests dominated by *Warburgia ugandensis, Olea africana, Diospyros abyssinica, Ficus* spp. and *Acacia* spp (Newsome *et al.*, 2004).

Figure 3.2: Main vegetation types in the Mara Ecosystem (Department of Resource Surveys and Remote Sensing, 2011)

3.2.3 Socio-economic background

The Maasai Mara National Reserve (MMNR) was first gazetted in 1948 as a Wildlife Sanctuary with regulated hunting. In 1961, the borders were extended east of the Mara River to encompass an area of 1,831 Km^2 and it was converted to a Game Reserve (Thompson *et al.*, 2009) whose control was vested in the Narok County Council (NCC) (Waithaka, 2004). The surrounding area, which is more than twice the reserve, was divided into hunting and photographic concession areas (Honey, 2009). In 1984, following discussions between the Council and Government to reduce its size, 321 Km^2 of land in the northeast, southeast and mid-north sections of the reserve were excised through formal notice and handed back to the local community reducing the MMNR to its current size of 1,510 Km^2. In 1995, the control of the MMNR was divided between the Narok and Trans Mara County Councils when the latter (known as the Mara Triangle) was formed out of the western part of the Reserve. In May 2001, the Mara Triangle , the north-western section of the reserve, was put under the management of the Mara Conservancy, a not-for-profit organization (Karanja, 2003). The two management authorities collect gate fees and revenue from facilities located in the gazetted reserve. Lodges and camps located outside the reserve's boundary remit occupation, concession and viewing fees directly to wildlife and tourism associations comprised of local communities. This study relies on the assumption that there is no significant difference in the abundance of wildlife between the Triangle and Narok sections of the reserve as evidenced by wildlife counts carried out in the ecosystem (Reid *et al.*, 2003).

The Mara has undergone significant changes since the Kenyan interior was first penetrated by Europeans at the beginning of the 20^{th} Century. Prior to this period, the Maasai who occupied the land grazed their cattle over wide areas of southern Kenya, migrating with their livestock in response to climatic changes (Waithaka, 2004). A rapidly growing human population [Narok County recorded 850,920 people in the last national census (Kenya National Bureau of Statistics, 2010b)] has seen a move from pastoralism to a more sedentary lifestyle by the Maasai. Norton-Griffiths (2007) explains that these changes, from pastoral land under communal tenure where wildlife can co-exist in the interstices, to an agro-pastoral and agricultural land use system under private tenure, make it difficult for wildlife to co-exist with the local community. The establishment of MMNR was seen by the locals as a move to exclude them from the management of their resources in order to protect wildlife for tourists. This caused a rift between the government and local people (Waithaka, 2004) and has been exacerbated by the increasing competition with wildlife outside the reserve for grazing, resulting in human-wildlife conflict (Walpole *et al.*, 2003).

The region enjoys moderately high rainfall and fertile soils giving it good agricultural potential. Ojwang' *et al* (2006) note that between 1985 and 1995, major land-use changes have occurred with areas which once acted as wet season range for a number of wildlife species being converted to agricultural land. There are concerns from scientists and wildlife managers that this conversion from rangelands to agricultural land coupled with climatic change will have a significant and damaging impact on wildlife and livestock in the ecosystem (Sindiyo, 2010, Ogutu *et al.*, 2009, Ogutu *et al.*, 2011). A government campaign in the 1970s to promote wheat growing in the northern part of the ecosystem has made it one of the highest wheat and barley producer in the country (Waithaka, 2004) and has seen large-scale farms of wheat, maize, barley, soya beans and sorghum cover the landscape towards the north in Lemek and Ol Kinyei, mostly owned by non-Maasai. Land under farming around the Mara has increased by 90% from 12,500 acres of farmland in 1975 to 125,000 acres in 1995 (Honey, 2009). By 2010, the distance of the nearest farm to the MMNR boundary was 17 km in Ololaimutia (BirdLife International, 2010, Ogutu *et al.*, 2009) having reduced from 52 km in 1975 (Waithaka, 2004).

3.2.4 Land use changes in the Mara Ecosystem

In East African savannahs, habitat loss and wildlife decline are generally attributed to rapid human population growth and the spread of subsistence cultivation. However, in the Mara-Serengeti ecosystem, the Mara side shows a rapid land use cover change and drastic decline for a wide range of wildlife species, concerns that are absent on the Serengeti side (Homewood *et al.*, 2001). According to Serneels and Lambin (2001a), this ecosystem, once a vast wildlife area with few pastoral settlements is rapidly becoming an island of native species surrounded by areas with intensifying land use.

The major land uses in the Mara are pastoralism, tourism and agriculture. Land use in the MMNR which is under the jurisdiction of the Narok and Trans Mara County Councils, is restricted to wildlife tourism, with periodic cattle grazing, although this is technically illegal (Thompson *et al.*, 2009). Ottichilo *et al.* (2000) states that the reserve's major conservation value is the protection of resident wildlife communities and the provision of dry season grazing for migratory wildlife populations such as the wildebeest. Surrounding the MMNR are group ranches which are either owned by individual families or groups of families, with the main land uses being pastoralism and agriculture. They however contain year-round resident wildlife populations with migrants visiting them in the dry season. There are no barriers to wildlife movement between these ranches and the adjacent protected Maasai Mara National Reserve (Ogutu *et al.*, 2010).

Changes in land use have been underlined as a major driver of habitat modification which can have important implications for the distribution of species and therefore for entire ecological systems (Serneels and Lambin, 2001a). Only 25% of the wildlife habitat in the Mara Ecosystem is within the gazetted reserve with the rest lying within pastoral and agricultural areas north of the reserve. Those lands are under more pressure than the rest of the ecosystem with recent unprecedented human population growth which has increased nearly 25-fold between 1957 and 2002 (Lamprey and Reid, 2004b), expansion of wheat farming in past previous wildebeest calving grounds (Serneels and Lambin, 2001a), the expansion of tourism facilities (Reid *et al.*, 2003, Serneels and Lambin, 2001a) and the development of trading centres and settlements near the reserve's main entrances and within the group ranches (Lamprey and Reid, 2004b, Thompson and Homewood, 2002).

Studies show that the most important change in this ecosystem's land cover is related to the conversion of rangelands where communal ownership of land has been replaced by individual ownership of small land parcels for subsistence farming in place of pastoralism, which is seen as being less profitable. (White *et al.*, 1997, Serneels and Lambin, 2001a, Ottichilo *et al.*, 2000, Honey, 2009). The resulting fixed, small land-holdings are widely regarded as ecologically unviable and unable to reliably support either farming or ranching. They also impede wildlife movement and increase human-wildlife conflict incidents. According to Osborne *et al.* (2001), many wildlife species are affected by human induced land use changes over large spatial areas. The wildlife population dynamics in the Mara are driven by changing climatic forces, progressive habitat deterioration and increased livestock incursions into the gazetted reserve as well as an increasing number of human settlements. Wildlife counts carried out periodically since the late 1950's show a noticeable change in wildlife migratory and distribution patterns in the greater Mara-Serengeti Ecosystem. (Ottichilo *et al.*, 2000, Ogutu *et al.*, 2009).

Conservation efforts have so far focused on maintaining biological diversity primarily by minimising exposure to human activities through the establishment of protected areas. However, new methods are required to predict the potential impacts of human activities on biological diversity across a hierarchy of spatial and temporal scales to make land use planning both clearer and better informed. Research is needed to understand how the Mara Ecosystem might evolve over time and how herbivores in this ecosystem are reacting to the increased human impact on their habitats (Serneels and Lambin, 2001a, Serneels *et al.*, 2001). The use of spatio-ecological approaches to define ecological zones where critical behaviours are most likely to take place and capture wildlife response to anthropogenic impacts have been suggested as a way of managing wildlife-tourist interactions by Higham and Lusseau (2007) and will be employed by this research.

3.2.5 Tourism development in the Mara Ecosystem

While it is twelve times smaller than the neighbouring Serengeti Ecosystem, the Mara Ecosystem receives more visitors. The MMNR is Kenya's highest earning protected areas, grossing $15 - 25 million per year (Norton-Griffiths cited in (Thompson *et al.*, 2009). 17% of Kenya's tourists visit the Mara annually making it one of the country's most popular attractions (Ministry of Tourism and Wildlife, 2008). Before the 1997 tourism slump, 332,000 visitors were recorded as staying for an average of 2.5 days and generating more than $50 million from accommodation tariffs, entry fees, game drives, ballooning, camping and transportation (Waithaka, 2004). This escalation of tourism has added to the challenges facing the Mara Ecosystem as the change in land ownership patterns has resulted in the majority of tourism enterprises being controlled by wealthy individuals (Honey, 2009).

The growth of tourist facilities aimed at accommodating the ever increasing number of tourists in the ecosystem is putting pressure on resources, particularly fuel load as well as supporting infrastructure such as roads and water resources, with many of them located within close proximity to permanent rivers and along the reserves boundary (Figure 3.4). Little consideration has, however, been given to how many tourist facilities this ecosystem can support. A major challenge facing the Mara's management is determining its carrying capacity while taking into account the increased visitation by local and foreign visitors to the area and accommodating these visitors whilst preserving the ecosystem's ecological integrity. The Mara reveals how struggles over land, wildlife and tourism can undermine ecotourism's underlying concept (Honey, 2009). As part of this research, tourist facilities in the ecosystem were geo-referenced taking into account size, year of establishment and development type (Figs. 3.3, 3.4 & 3.5).

In 1962, the NCC which had been granted the responsibility of developing tourism facilities in the MMNR, built the first permanent tourist facility which consisted of a number of self-catering *bandas* (thatched-roof bungalows) (Honey, 2009). In 1965, Keekorok Lodge replaced the self-catering *bandas* with 25 beds along with two resident vehicles (Waithaka, 2004) paving the way for the establishment of more facilities inside the reserve. All subsequent tourist facilities in the MMNR have been built by private developers, who lease the land from the NCC (Honey, 2009, Karanja, 2003).

After the hunting ban was imposed in 1977, former professional hunters were encouraged to establish permanent tented camps in the former hunting and photographic concession blocks within the group ranches neighbouring the reserve making them the first facilities developed outside the reserve (Karanja, 2003). In the same year (1977), the international border between Kenya and Tanzania was closed making the Maasai Mara the terminus of the popular Serengeti -Ngorongoro crater circuit. This popularity caused a sharp rise in visitor numbers and coupled with the hunting ban, triggered inadequately planned development of ecotourism infrastructures (Honey, 2009). The development of tourist facilities inside and outside the reserve has continued to present day, despite the declaration of a moratorium on further establishment of facilities in 2008. Figure 3.4 demonstrates the exponential growth of tourist facilities and increase in number of beds available for tourists in the Mara over the past 20 years.

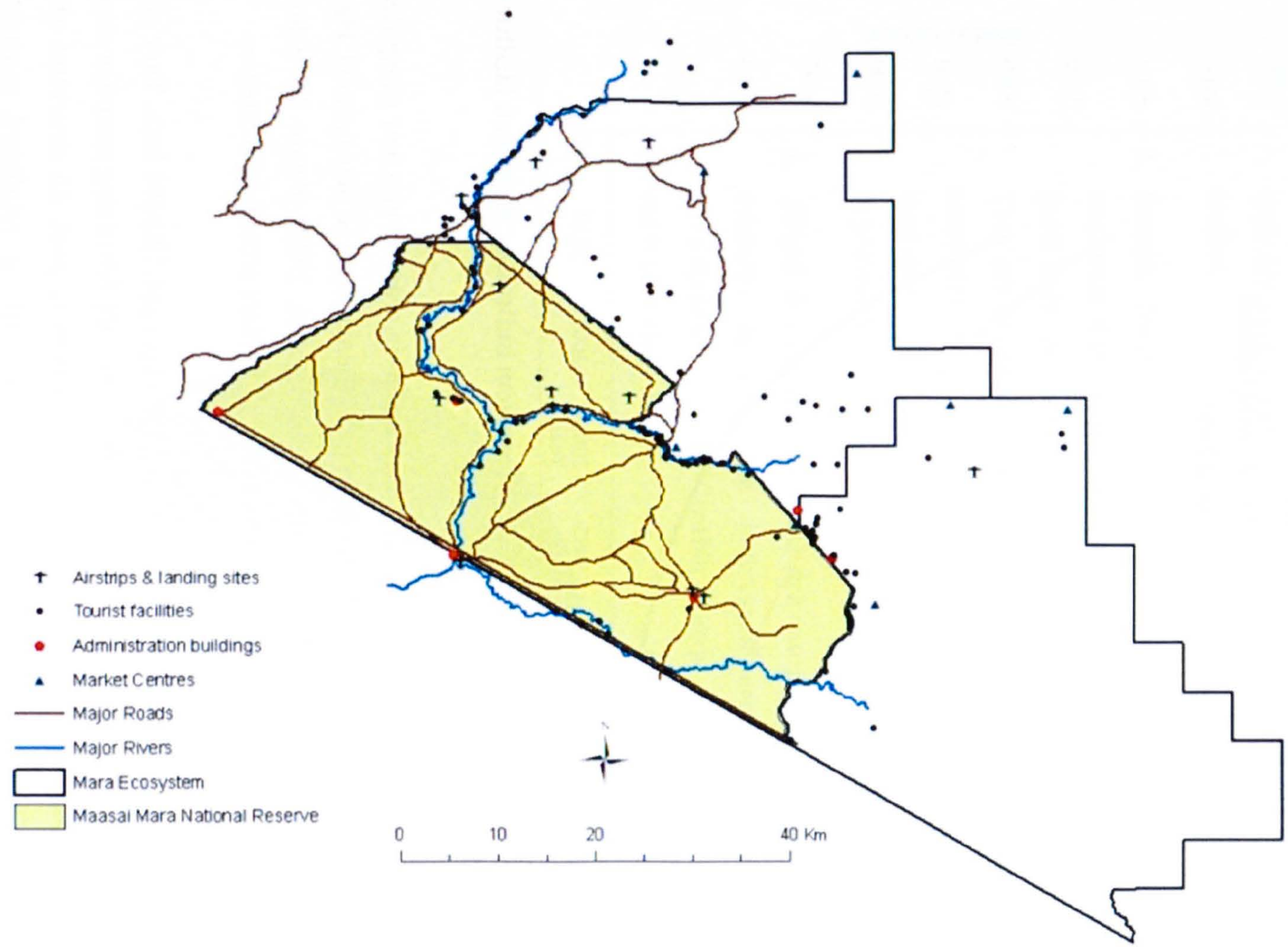

Figure 3.3: Tourist facilities and supporting infrastructure in the Mara Ecosystem

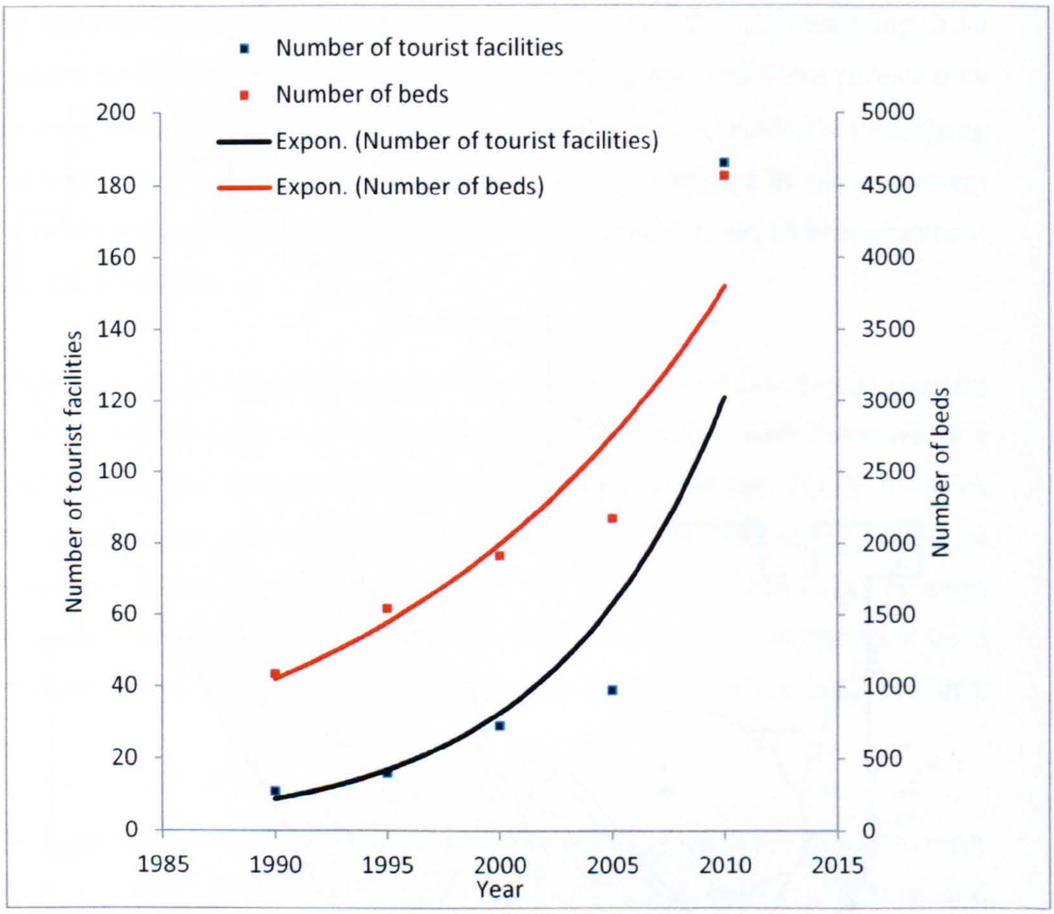

Figure 3.4 Tourism growth in the Mara Ecosystem indicating increased facilities and bed numbers

Tourist accommodation in the Mara Ecosystem has been grouped into four categories as described in the 2008 – 2018 Maasai Mara National Reserve Management Plan (Narok County Council and Trans Mara County Council, 2008). Figure 3.5 below demonstrates the composition of tourist facilities in the Mara according to category.

1. **Lodges:** These are generally large facilities of around 100-200 beds. They are permanent single or multi-levelled facilities typically containing reception area, gift shop, dining room(s), bar(s) and a swimming pool. All structures are generally made from permanent materials such as reinforced concrete, although guest bedrooms are often under canvas with a thatched or wooden shelter. However, floors and bathrooms are typically made from concrete or other permanent materials.

2. **Tented camps:** These facilities are designed and constructed to have a small visual and environmental impact, and usually seek to create a more natural ambiance and visitor experience than traditional lodges. They are restricted to a single level, which may have a permanent cement or wooden platform, and typically have a tented (or other natural material, such as wood and thatch) shelter.

3. **Camps:** These are small, temporary facilities that are taken down for a minimum of three months each year, and that contain no permanent structures (with only concealed plastic plumbing allowed to remain at the cleared site). They are designed to have minimal visual and environmental impacts. Special campsites are small, designated sites within the reserve where commercial operators establish temporary and very high standard tented camps which aim to provide visitors with a unique wilderness-style camping experience

4. **Mixed developments:** These are tourist developments that encompass a mixture of permanent and semi-permanent accommodation. These developments include within them both lodge and tented camp accommodation.

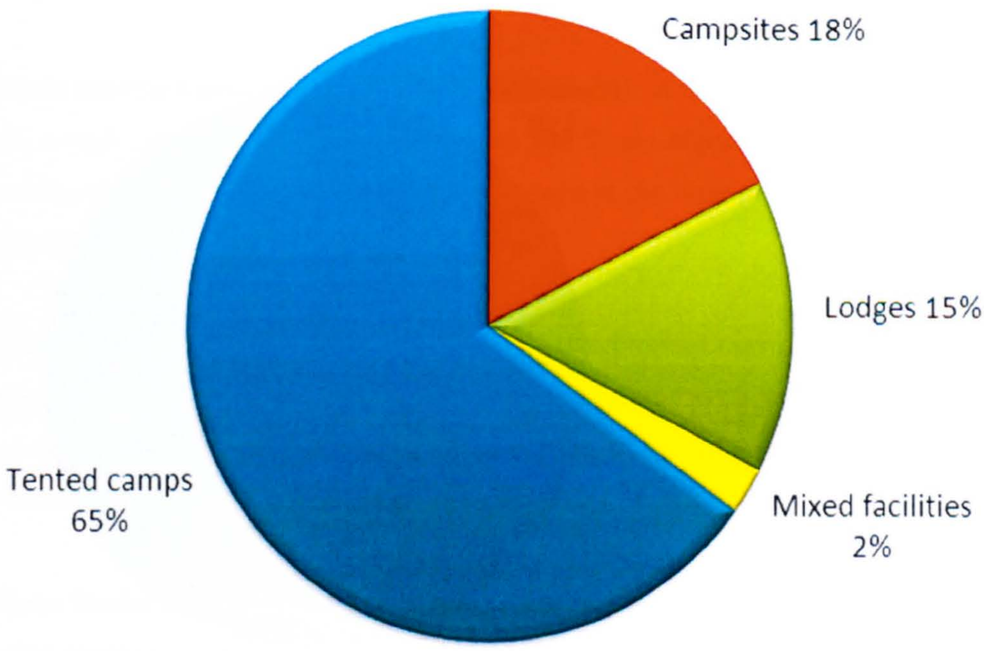

Figure 3.5 Categories of tourist facilities in the Mara

3.2.6 Ecotourism in the Mara

Kenya has been a mass tourism destination for a long time and is now shifting towards embracing principles and practices of ecotourism. Several facilities in the Mara, mostly located in conservancies, are moving toward ecotourism principles with a preference towards more controlled, small scale sustainable tourism developments (Honey, 2009).

Eco-rating is done by Ecotourism Kenya (EK), a civil organization with varied membership, which manages the certification scheme for tourism accommodation based on environmental and social criteria. After a self-assessment exercise, an audit is then undertaken by an independent assessor who reviews the applications and verifies compliance with the criteria and makes recommendations for certification. Successful applicants are awarded a certificate of recognition (Gold, Silver or Bronze rating according to their levels of compliance) and are allowed to use the scheme logo on their property and on promotional material. Ratings are valid for two years after which businesses need to reapply if they wish to continue to use the scheme logo (Ecotourism Kenya, 2011). 18% (Figure 3.6) of the Mara's tourist facilities are certified by Ecotourism Kenya.

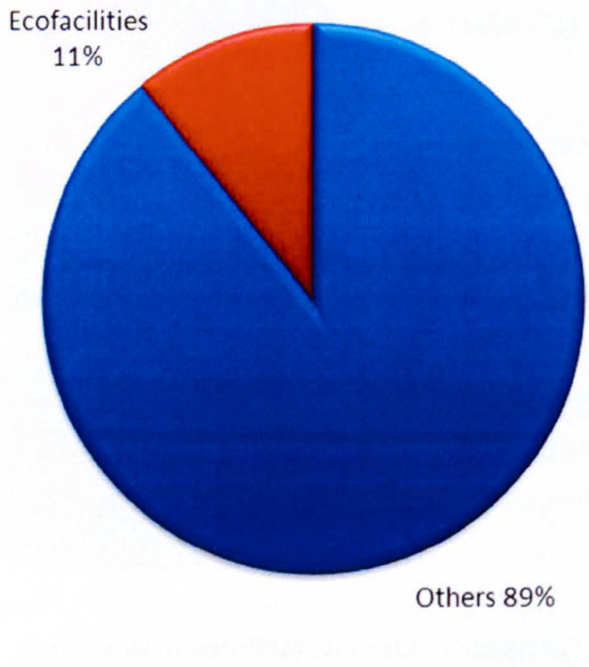

Figure 3.6 Proportion of eco-rated facilities in the Mara Ecosystem

3.3 Study sites

For the purpose of this study, six tourism developments (3 tented camps and 3 lodges) have been selected as case studies in the Mara Ecosystem (Figure 3.7). These developments are intended to represent accommodation types across the ecosystem. Three of the study sites are eco-rated by Ecotourism Kenya.

1. **Sekenani Camp** (S0132.948 E03522.460): A 15 tented camp was established in 1989 located in the Sekenani Valley at the foothills of Ngama Hill beside a permanent spring. It is located 6 Km from Sekenani Gate and is adjacent to the reserve's boundary with community land.

2. **Keekorok Lodge** (S0135.9 E03514.15): The 101 room lodge was the first tourist development to be constructed within the Park boundaries in 1962. It is located on the Narok side of the reserve in an area with springs and swamp.

3. **Basecamp Maasai Mara** (S0127.279 E03512.909): A 15 tented eco-camp located close to Talek gate and along the Talek River outside the park boundary and in close proximity to other developments. Its unique approach to sustainability is combined with community development and cultural interactions. (Gold rated facility)

4. **Mara Serena Safari Lodge** (S0124.09 E03501.34): A large scale lodge located on a high ridge along the Mara River on the Trans Mara side of the reserve within the Mara Triangle. It has 74 rooms and is the only permanent lodge in the Triangle. (Bronze rated facility)

5. **Mara Porini Camp** (S0124.726 E03524.257): A 6 tented camp is located along the banks of Laetolo, a permanent spring. It is located within the 12 000 acre exclusive Ol Kinyei wildlife conservancy within Ol Kinyei group ranch. (Silver rated facility)

6. **Mara Simba Lodge** (S0128.338 E03517.733): A mixed development consisting of 84 permanent stone and tented rooms. It is located along a bend of the Talek River and sits astride the reserve boundary and community land.

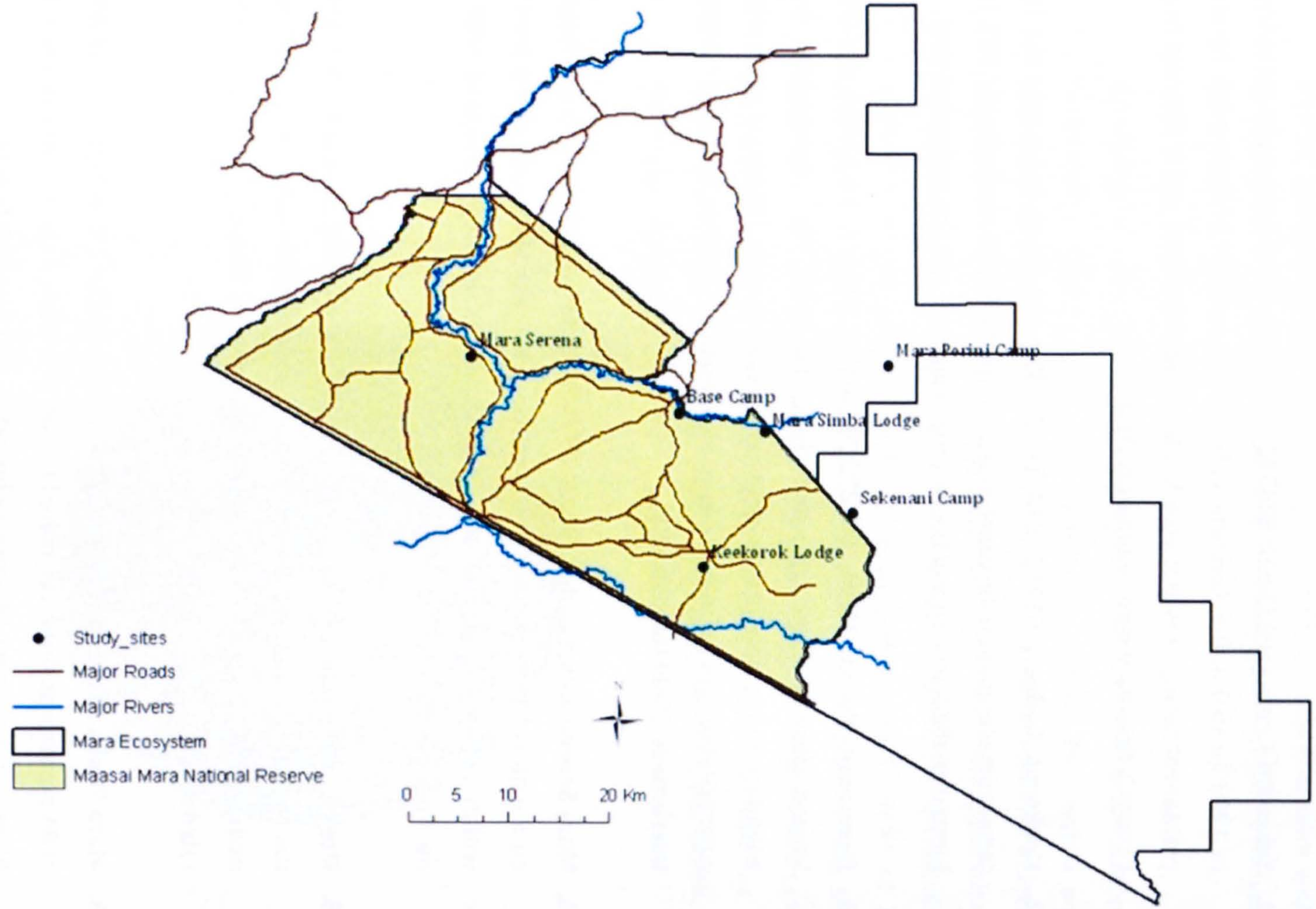

Figure 3.7 Map of the Mara Ecosystem showing study sites

3.4 Research gap

The difficulty in achieving "complete" sustainability within the East African wildlife tourism industry has been attributed to extraordinary expansion of ecotourism and the increasing pressures of demand for access to natural areas. The environmental effects caused by overcrowding, overdevelopment, pollution, wildlife disturbance and vehicle use should be seen as more serious for ecotourism than mass tourism (Wearing and Neil, 1999). Buckley (2004b) emphasises that there seems to be little appreciation within the tourism industry and amongst protected area agencies of the complexity of ecological impacts, or to the time and resources required to carry out valid scientific ecological research.

As tourism continues to gain popularity, the number of tourists to wildlife areas continues to increase prompting an unprecedented rise in the development of tourist facilities to meet this demand. Subsequently, this has increased the pressure on local infrastructure and services e.g. roads, water and alternative electricity supplies and waste disposal systems. These have an obvious impact on the natural and physical environment and should therefore be subject to rigorous environmental procedures to formulate mitigation measures. Because of the short term research common within tourism studies, scientific monitoring and assessment of the long term nature of its potential impacts has been rendered difficult due to consistent neglect (Cole, 2004, Walpole *et al.*, 2003).

The documentation of existing scientific research in a form useful for managing wildlife tourism has been noted as currently being inadequate with little appreciation within the industry and protected area agencies on the complexity of ecological impacts, or the time and resources required to carry out valid scientific ecological research (Buckley, 2004b, Buckley, 2003). Rodger and Moore (2004) note that many wildlife studies focus on undisturbed behaviours rather than potential impacts such as behavioural disturbance or disruption, increased vulnerability to predation and disruption to breeding behaviour and parental care. Weaver and Lawton (2004a) in a literature review point out that while several studies have focused on protected areas from an ecotourism perspective, no effort has been made to identify major themes and trends pertinent to the ecotourism-protected area interface.

According to the WWF (World Wide Fund for Nature), although ecotourism is booming, much of its growth to date has been unsustainable (Denman, 2001). Existing eco-rating schemes focus mainly on how tourist facilities manage their waste, energy and grey water systems ensuring that their activities and those of their visitors have minimal impact on the environment (Watkin, 2002). They however do not explore impacts the facility has on local wildlife populations, principally in terms of changes to their traditional migratory paths, densities and any behavioural changes around the facility.

There is need for existing ecological research to move beyond the easily observable and measurable effects of tourism, and emphasise on the relationship between its physical, chemical and biological effects. Examining past records to identify migration patterns and distribution of wildlife populations and comparing them with current distribution data, this research aims to highlight changes in wildlife distribution and densities in relation to tourist developments.

3.5 Research Structure

The individual methodologies developed for this research are discussed in greater detail in the following chapters:

i. Chapter 4: Species response to tourist facilities
ii. Chapter 5: Long term ungulate response to increased tourism development and;
iii. Chapter 6: Suitability modelling to identify locations for future developments

Chapter 4

SPECIES RESPONSE TO TOURIST DEVELOPMENTS

4.1 Introduction

Human disturbance to wildlife is often seen as being important only if it directly affects survival and causes noticeable declines in populations (Gill *et al.*, 2001). To determine how individual responses of disturbed animals ultimately affect population dynamics and viability, it is necessary to demonstrate that human disturbance reduces individual fitness (Kerbiriou *et al.*, 2009). Most studies, especially on tourism's impacts, have focused on individual responses (Roe *et al.*, 1997) with little consideration given to responses at a population level. Identifying the resource requirements of a species is an important part in understanding the impacts of disturbance to wildlife populations (Zhou and Zhang, 2011) and consequently making appropriate conservation decisions.

To date, tourism impact on wildlife population have been difficult to measure, with existing studies failing to capture the complex interrelationships between different variables (Roe *et al.*, 1997) such as vegetation cover and distance to supporting infrastructure. A major objective of this study was therefore to evaluate wildlife response to tourism developments, taking into account the nature of disturbance, the type and size of the accommodation, habitat types, individual species and the season during which the disturbance occurs as outlined by Theobald *et al.* (1997).

4.2 Research questions

i. What are the anthropogenic impacts of different wildlife tourism developments (eco-facilities and traditional lodges) on key ungulate species in the Mara ecosystem?
ii. How do these ungulate species interact with the different types of tourist facilities?

iii. Are there any significant differences in species observations between eco-facilities and traditional lodges and are there seasonal differences in these observations?

4.3 Study species

This study focused on twelve ungulate species (table 4.1) which have previously been highlighted as affected by the land use changes occurring in this ecosystem (Ogutu *et al.*, 2009, Ogutu *et al.*, 2011). The selection of these study species was influenced by annual wildlife count data from DRSRS.

This research did not include wildebeest (*Connochaetes taurinus)* in its analysis of ungulate response to tourist developments. Most of the Mara Ecosystem's wildebeest are migratory and form part of the annual migration which occurs in the greater Mara-Serengeti Ecosystem. The Mara has a separate, smaller wildebeest population which are concentrated in the Loita plains and cover a small migration range between the Loita and Siana plains between January and June before eventually meeting with the Tanzanian wildebeest population in the Maasai Mara National Reserve (Serneels and Lambin, 2001a). This local population has however declined by up to 81% in the last 20 years due to the loss of former resident wildebeest wet season grazing, calving and breeding ranges to agriculture (Ottichilo et al., 2001). Even though Zebra (*Equus burchelli)*, Thompson's gazelle (*Gazella rufifrons)* and Grants gazelle (*Gazella granti)* also have migratory herds, they were included in this study as their year round resident herds are substantial in number and widespread in the ecosystem.

Table 4.1 Description of study species

Species	IUCN status	Home range (km²)†	Body mass (kg)	Habitat preference	Dietary guild	Degree of Water dependence	Dispersion pattern	Social Organization
Buffalo *(Syncerus caffer)*	NE	3-4	250-850	Savannah and savannah woodland	G	Strong	Resident	Highly gregarious and non-territorial. Large herds with male dominance hierarchy.
Eland *(Taurotragus oryx)*	LV	174-422	300-942	Grassland, woodland-savannah	B	Weak	Resident	Gregarious, non-territorial and nomadic.
Elephant *(Loxodonta africana)*	V	15-3700	2200-3500	All major vegetation types	MF	Strong	Resident	Females form matriarchal herds of related individuals and males form separate herds.
Giraffe *(Giraffa camelopardalis)*	LC	5-164	450-1930	Dry savannahs, open woodlands, seasonal floodplains	B	Strong	Resident	Gregarious, non-territorial, congregating in loose open herds.
Grant's Gazelle *(Gazella granti)*	LC	2.5-10	38-81.5	Arid scrubland and open woodland savannah	MF	Strong	Migratory*	Gregarious and territorial.
Thompson's Gazelle *(Gazella rufifrons)*	V	0.1-0.3	15-35	Open grassland and shrub savannah	G	Strong	Migratory*	Gregarious and territorial.
Topi *(Damaliscus lunatus)*	LC	19.1-80.6	75-160	Open woodland and scrub savannah	G	Weak	Resident	Rely on habitat type to assume perennially sedentary dispersed or mobile aggregated dispersion patterns.
Impala *(Aepyceros melampus)*	LC	8.5-80	45-60	Open and lightly wooded savannah	MF	Strong	Resident	Seasonally or perennially territorial, gregarious and sedentary.
Kongoni *(Alcelaphus buselaphus)*	LC	3.7-5.5	116-218	Boundaries between open grassy plains and parkland woodland or scrub	G	Strong	Resident	Distributed in sedentary-dispersed patterns with territorial males.
Warthog *(Phacochoerus africanus)*	LC	0.64-3.74	45-75	Savannah grasslands and open bushlands	G	Strong	Resident	Have matriarchal groups with home range shared by filial sounders, bachelors and solitary males.
Waterbuck *(Kobus ellipsiprymnus)*	LC	2-6	160-300	Savannah woodlands and forest-savannah mosaics near permanent water	G	Strong	Resident	Distributed as territorial semi-isolated units with bachelor males tolerated and often in proximity to females.
Zebra *(Equus burchelli)*	LC	30-600	175-322	Grasslands, steepes, savannahs and woodlands	G	Strong	Migratory*	Non-territorial, nomadic male harems and bachelor herds.

Notes: Abbreviations are: NE- Not Endangered; LV- Locally Vulnerable; V- Vulnerable; LC- Least Concern; B- Browers; G -Grazers; MF- Mixed Feeders

† Minimum and maximum ranges for different populations; *Have a considerable resident population in the study area outside the migration season.

Adapted from Estes (1992), Kingdon (1997) and Shorrocks (2007) and IUCN (2011)

4.4 Methodology

This study investigated the anthropogenic impacts of different wildlife tourism developments (ecolodges and traditional lodges) upon key ungulate species in the Mara ecosystem and took into account changes in these species' distribution and numbers. Attention focused on analysing spatial and temporal relationships of the twelve ungulate species during four survey seasons between 2009 and 2011 which were carried out during the country's high and low tourism seasons. Low season surveys were carried out between February and April and the high season surveys carried out between August and October, which coincide with the Northern hemisphere summer season and annual Mara-Serengeti wildebeest migration.

To assess the interactions between ungulate species and tourist developments, WildKnowledge© software was used. WildKnowledge enables the creation of mobile recording forms (using Wild Form) and incorporates GIS hardware. It was used in this research to store species specific spatial and temporal data collected over a two year period. Data was collected on distribution and activity types of focal wildlife species over the four survey seasons from static observation points in various sized accommodation currently utilised by visitors to the Mara.

To record and monitor trends in wildlife species around six selected developments (all in or within close proximity to the Maasai Mara National Reserve), point transects were conducted by a single observer during morning and evening peak observation times. Species detected within 1000m (1 km) and 180° field of vision of the static viewing points was considered present for the specified sampling occasion (Fig 4.1). The following were recorded during each observation session:

i. Time of day
ii. Species distance from static point in selected facilities lodge. A Bushnell Pin Seeker 1500 range finder was used to record wildlife distance sightings of up to 1000m.
iii. GPS (Global Positioning System) location recorded using an inbuilt GPS in the mobile recording device
iv. Species numbers
v. Core wildlife behaviour

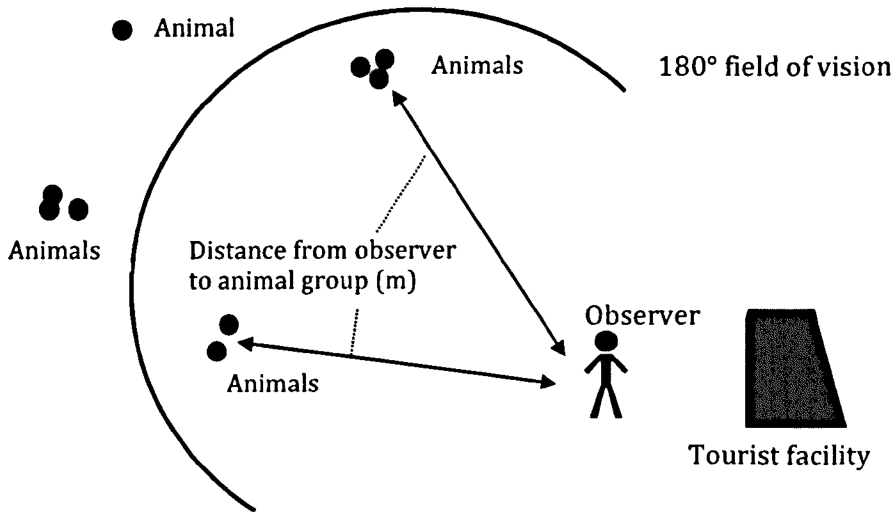

Figure 4.1 Data collection protocol

4.4.1 Appraisal of methodology

The number of animals observed in a sample is considered an estimate of the true density and probability of detection, which is a function of many factors including observer effectiveness and the environment (Hidinger, 1999). The following assumptions were made in this study during data collection;

i. It was assumed that all animals around the selected developments were detected and their distances and group size correctly recorded.

ii. It was assumed that the animals were detected at their original location, before any movement resulting from the observer's presence. Animals move both in response to humans and of their own will which may increase or decrease their likelihood of being observed (Hidinger, 1999). Tour and service vehicles leaving and arriving to the lodges may have also caused animal flee response.

iii. It was assumed that the presence of tourists and lodge staff resulted in secretive animals being missed as result of them fleeing unnoticed or hiding. Habituation to humans especially among certain herbivores such as Impala and Bushbuck decrease their inclination to flee and increase their possibility of being observed thus skewing the density estimates.

iv. It was assumed that occasional predator presence around the study sites resulted in the absence of study species on these occasions.

4.5 Data Analysis

4.5.1 Natural and anthropogenic impacts to species distribution

GIS overlay techniques were used to identify and relate environmental factors most likely to affect wildlife presence around tourist developments. The following were considered during this study and subsequent analyses.

Table 4.2 Table of independent variables considered in the study

Independent variables	Description
Habitat classes **(HABITAT)**	Binary values from 2 - 41 of habitat classes present in the Mara Ecosystem
Distance to River **(DISTRV)**	Continuous variable, measuring distance to permanent rivers (km)
Distance to other lodges **(DISTLDG)**	Continuous variable, measuring distance to other lodges (km)
Lodge type **(TYPELDG)***	Binary value, 2 for eco-lodges and 3 for traditional lodges
Tourism Season **(TSEASON)***	Binary value, 1 for high tourism season and 2 for low tourism season
Distance to roads **(DISTRD)**	Continuous variable, measuring distance to nearest major road** (km)
Species distance **(DISTSPP)***	Continuous variable, measuring species distance from study site (m)
Species behaviour **(SPPBHVR)**	Categorical values from 1-4 of species behaviour during observations
Species numbers **(SPPNOS)***	Continuous variable, measuring number of observed species

* Included in statistical analysis using the Kruskal-Wallis test, **All-weather roads maintained by the local councils and used for access to tourist accommodation.

4.5.1.1 Habitat availability

A satellite image vegetation map was obtained from the Kenya Wildlife Service (KWS); and 22 habitat classes were extracted from it using GIS tools to create a habitat mosaic of the study sites. Wildlife observations in the selected sites were restricted to a 1km radius due to visibility and range finder field of vision. Using a GIS, these observation areas were clipped from the ecosystem map layer by creating 1km buffers to show habitat composition. To account for any change in habitat composition which could influence ungulate presence, 3km buffers were also created (Tables 4.3 and 4.4) to enable understanding of the surrounding areas. 3 km was selected as a comparison distance due to the close proximity of lodges to each other, especially in the Sekenani and Talek areas, which could influence habitat composition due to clearance and over utilisation. Wildlife have been observed to remain in areas of disturbance when there is a lack of alternative habitat but will avoid these areas where alternative habitat exists (Gill *et al.*, 2001).

A. HABITAT ANALYSIS - LINEAR REGRESSION

Due to the small sample size within the ecosystem (only six developments selected out of a possible 180), vegetation cover was not included as a covariate in the statistical models. However, site by site analysis showed similar habitat types and cover within both 1km and 3 km of the study sites (Figure 4.3 and Appendix 1). This was taken as an indication that habitat type was not a major influence in species presence around the selected developments. To measure the relationship between habitats in the core viewing area and ring areas, a linear regression model was run (Figure 4.4) for each study site;

$\mathbf{y = \beta_0 + \beta_1 x + e}$ where; y = core area, x = ring area, $\beta 0$ = the intercept and $\beta 1$ = the slope

The regression analyses showed correlation between habitat classes and cover between the core and ring areas with strong relationships in Mara Porini Camp (R^2= 0.90), Mara Serena Lodge (R^2= 0.88), Mara Simba Lodge (R^2= 0.63), Basecamp (R^2= 0.63) and Keekorok Lodge (R^2= 0.57). Sekenani Camp displayed a weaker correlation (R^2=0.34) indicating that only 34% of total variation in the core and ring habitat areas could be explained by the model. Re-examination of the raw data and ground truthing of this site showed that its location within close proximity of an extensively utilized community area and subsequent difference in habitat cover between the two regions may be a result of overgrazing by livestock and harvesting of firewood by the local community.

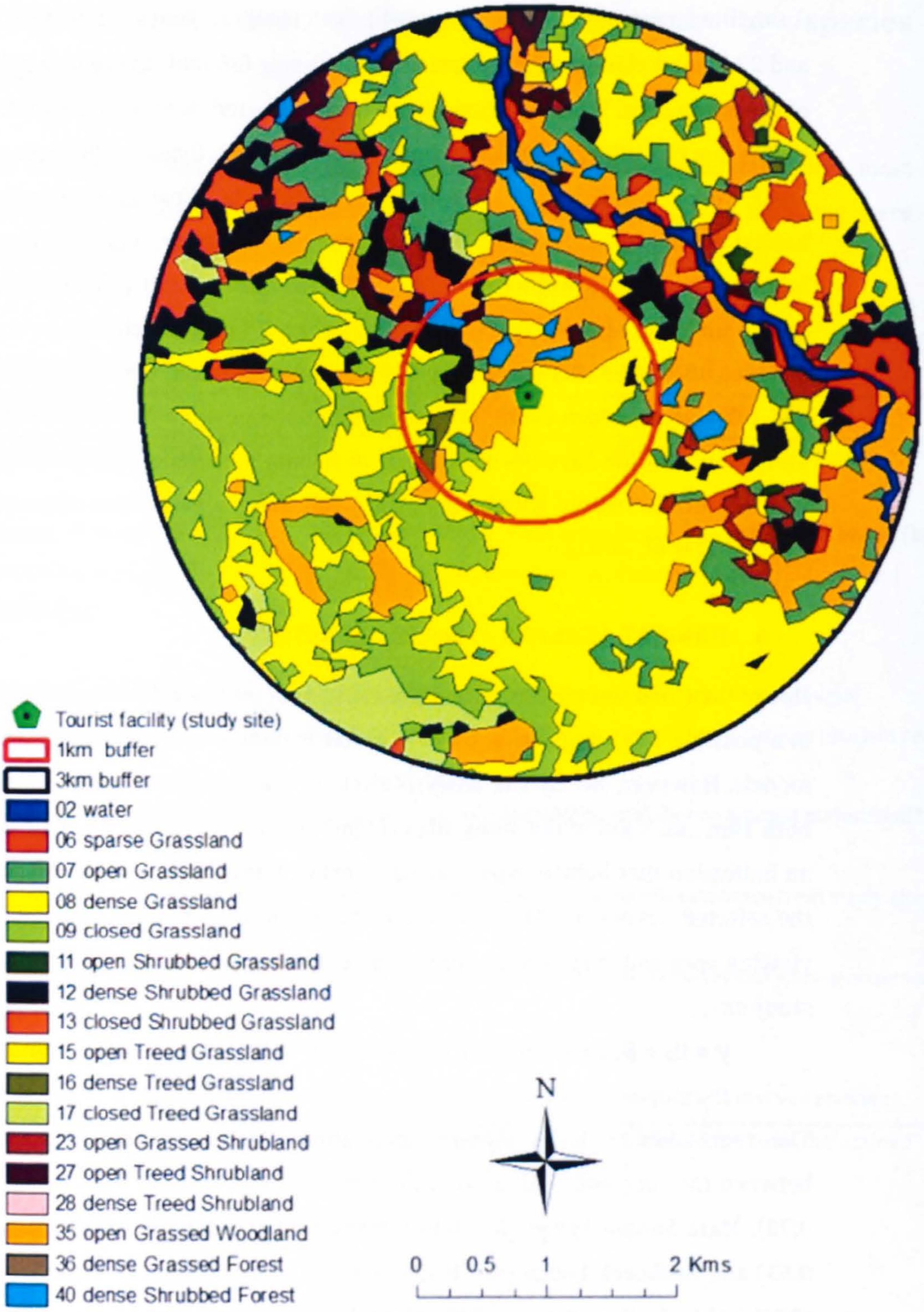

Figure 4.3 Habitat classes in 1km and 3km buffers around a selected study site (*Serena Lodge*)

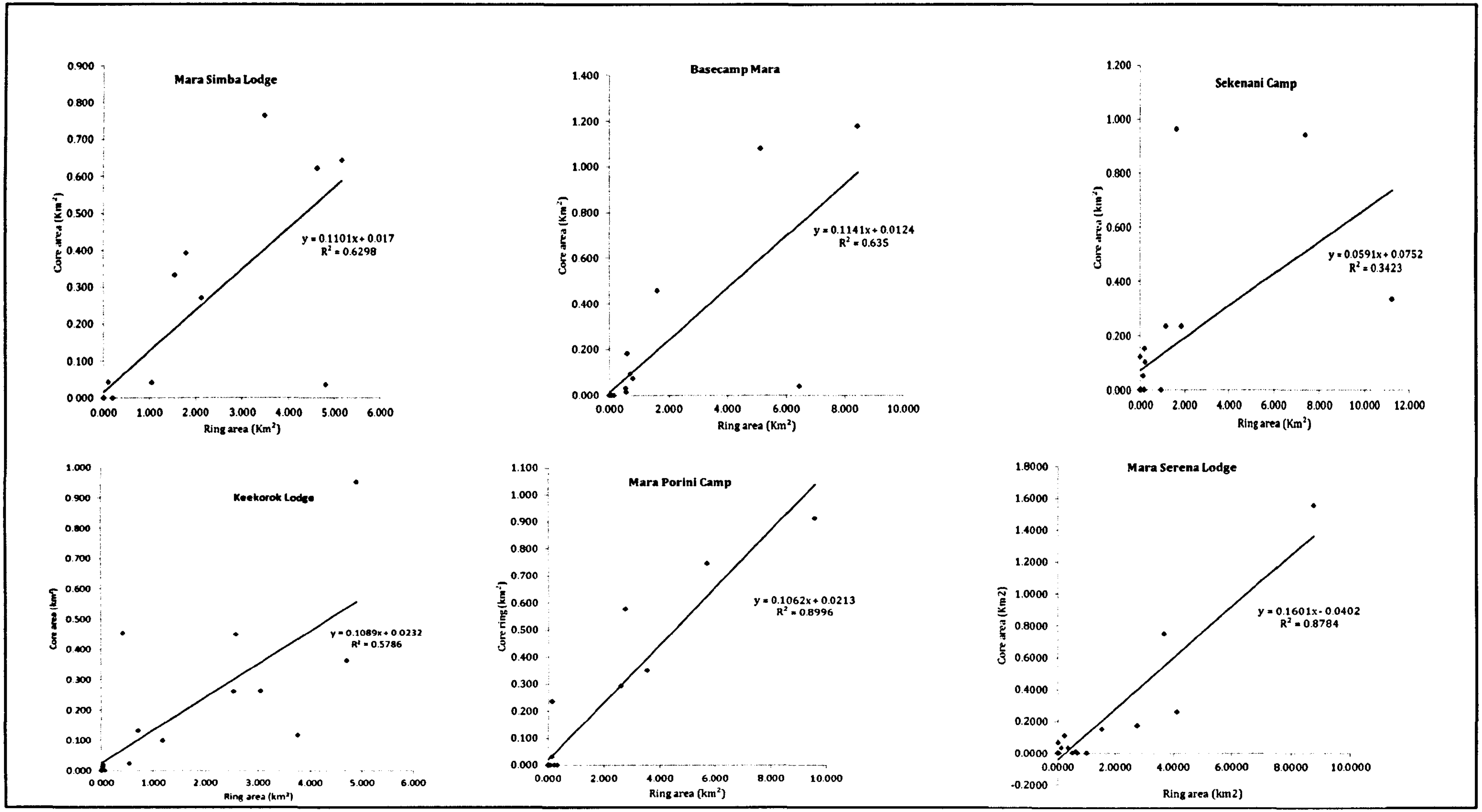

Figure 4.4 Scatterplots of ring area against core area fitted with a linear regression model

Table 4.3 Habitat classes within 1km (core area) and 3 km (ring area) radii of study sites

	STUDY SITES					
HABITAT CLASS	**Basecamp Mara**	**Mara Porini**	**Mara Simba**	**Mara Serena**	**Keekorok Lodge**	**Sekenani Camp**
Sparse grassland [6]	+ *	*	+ *	*	+ *	+ *
Open grassland [7]	+ *	*	+ *	+ *	+ *	+ *
Dense grassland [8]	+ *	+ *	+ *	+ *	+ *	+ *
Closed grassland [9]	*	*	*	+ *	+ *	*
Open shrubbed grassland [11]	+ *	+ *	+ *	*	*	-
Dense shrubbed grassland [12]	+ *	*	+ *	+ *	+ *	+ *
Closed shrubbed grassland [13]	+ *	*	+ *	+ *	+ *	-
Open treed grassland [15]	*	+ *	*	+ *	*	+ *
Dense treed grassland [16]	*	+ *	-	+ *	+ *	+ *
Closed treed grassland [17]	-	-	-	*	+ *	*
Open grassed shrubland [23]	+ *	+ *	+ *	+ *	+ *	*
Dense grassed shrubland [24]	*	-	-	-	-	-
Closed grassed shrubland [25]	-	-	-	-	-	-
Open treed shrubland [27]	+ *	+ *	+ *	+ *	+ *	+ *
Dense treed shrubland [28]	-	-	-	*	-	*
Closed treed shrubland [29]	-	-	-	-	-	-
Open grassed woodland [35]	+ *	+ *	+ *	+ *	+ *	+ *
Dense grassed forest [36]	*	-	-	*	+ *	+ *
Open shrubbed woodland [39]	-	-	-	-	*	-
Dense shrubbed forest [40]	-	-	-	+ *	-	*
Closed shrubbed forest [41]	-	-	-	-	-	-

[+] present within 1km radius of study site, [*] present within 3km of study site, [-] not present within 3km of study site

Table 4.4 Percentage (%) habitat cover within 1km (core area) and 3 km (ring area) radii of study sites

HABITAT CLASS	STUDY SITES											
	Basecamp Mara		Mara Porini		Mara Simba		Mara Serena		Keekorok Lodge		Sekenani Camp	
	1 km	3 km	1 km	3 km	1 km	3 km	1 km	3 km	21 km	3 km	1 km	3 km
Sparse grassland [6]	2.93%	2.79%	-	0.13%	8.60%	8.46%	-	1.88%	0.57%	0.20%	4.81%	1.22%
Open grassland [7]	37.52%	34.03%	-	1.18%	19.78%	18.56%	5.51%	10.4%	3.15%	4.54%	29.98%	29.45%
Dense grassland [8]	1.24%	22.94%	29.01%	37.12	1.12%	17.15%	49.54%	36.51%	3.76%	13.75%	7.52%	7.47%
Closed grassland [9]	-	0.55%	-	0.77%	-	0.64%	8.28%	15.49%	8.31%	9.90%	-	3.27%
Open shrubbed grassland [11]	5.76%	2.74%	18.34%	11.73%	12.45%	7.77%	-	0.17%	-	1.14%	-	-
Dense shrubbed grassland [12]	34.39%	22.00%	-	0.22%	20.48%	20.60%	4.81%	5.95%	11.56%	17.94%	3.28%	1.14%
Closed shrubbed grassland [13]	0.41%	2.00%	-	0.35%	1.37%	0.53%	0.06%	3.58%	14.26%	10.74%	-	-
Open treed grassland [15]	-	0.14%	11.08%	13.69%	-	0.71%	1.02%	0.59%	-	0.88%	30.65%	9.20%
Dense treed grassland [16]	-	0.06%	7.49%	1.27%	-	-	2.13%	0.31%	4.17%	2.99%	7.52%	4.96%
Closed treed grassland [17]	-	-	-	-	-	-	-	2.47%	8.34%	11.70%	-	0.04%
Open grassed shrubland [23]	2.26%	3.02%	9.30%	10.81%	1.31%	3.87%	0.35%	2.31%	0.73%	2.01%	-	0.03%
Dense grassed shrubland [24]	-	0.27%	-	-	-	-	-	-			-	-
Closed grassed shrubland [25]	-	-	-	-	-	-	-	-			-	-
Open treed shrubland [27]	14.52%	7.33%	0.96%	0.57%	10.57%	6.66%	1.02%	1.45	14.42%	3.10%	1.63%	0.62%
Dense treed shrubland [28]	-	-	-	-	-	-	-	0.06%	-	-	-	0.64%
Closed treed shrubland [29]	-	-	-	-	-	-	-	-	-	-	-	-
Open grassed woodland [35]	0.96%	2.00%	23.76%	22.79%	24.33%	15.01%	23.83%	15.69%	30.31%	20.69%	10.70%	40.92%
Dense grassed forest [36]	-	0.14%	-	-	-	-	-	0.04%	0.41%	0.16%	3.92%	0.44%
Open shrubbed woodland [39]	-	-	-	-	-	-	-	-	-	0.27%	-	-
Dense shrubbed forest [40]	-	-	-	-	-	-	3.44%	1.23%	-	-	-	0.62%
Closed shrubbed forest [41]	-	-	-	-	-	-	-	-	-	-	-	-

B. Habitat Analysis - Paired sample t-test

To further analyse the habitat composition around the study areas, the 22 classes were reclassified into 9 broad habitat classes as follows to allow for graphical representation.

1) Sparse grassland + open grassland +dense grassland +closed grassland = **Grasslands**
2) Open shrubbed grassland +dense shrubbed grassland + closed shrubbed grassland = **Shrubbed grassland**
3) Open treed grassaland + dense treed grassland +closed treed grassland = **Treed grassland**
4) Open grassed shrubland + dense grassed shrubland + closed grassed shrubland = **Grassed shrubland**
5) Open treed shrubland + dense treed shrubland + closed treed shrubland = **Treed shrubland**
6) Open grassed woodland = **Grassed woodland**
7) Dense grassed forest = **Grassed forest**
8) Open shrubbed woodland = **Shrubbed woodland**
9) Dense shrubbed forest + closed shrubbed forest = **Shrubbed forest**

To further test for similarity in habitat composition, paired-sample t-tests with Bonforreni adjustment were conducted at each study site to compare habitats at 1km and 3 km radii. The following hypothesis was tested;

H_o: There is no difference in habitat composition within 1km and 3km radii of the study sites.

H_1: There is a difference in habitat composition within 1km and 3km radii of the study sites.

There was no significant difference in habitat composition at 1km and 3km for all the study sites. These results (Table 4.5) show that habitat did not vary further away from the study sites and therefore was not an influencing factor on species presence in these areas.

Table 4.5 Paired-sample t-tests for habitat composition within1km and 3km radii

Study site	df	t value	*p*
Basecamp Mara	6	-0.0022	0.4992*
Mara Porini Camp	5	-0.0008	0.4997*
Mara Simba Lodge	5	-0.0011	0.4996*
Mara Serena Lodge	8	-0.0017	0.4993*
Keekorok Lodge	9	-0.0019	0.4992*
Sekenani Camp	7	-0.0004	0.4998*

df= degrees of freedom for number of habitats, *no significant difference -accept H_o (using Bonforreni adjustment, p>0.0083)

Pie charts (Appendix 2) were created to show habitat coverage at each of the sites. Grassland dominated all the study sites with a coverage of up to 64% around Serena Lodge. The grassed forest class was the least common habitat at the study sites with a maximum coverage of 4% at Sekenani Camp. Grassed woodland was abundant in all the sites but Mara Simba and Basecamp, both which are located along the Talek River. The presence of human settlements close to these facilities indicates that there may be harvesting of wood by the local communities. Sekenani Camp had the lowest area covered by shrubbed grassland which may be due to high grazing pressures from neighbouring *manyattas* (traditional Maasai homesteads). Although all the study sites are located close to permanent water sources (Fig 4.5), only Mara River was captured in the satellite vegetation map and classed as a habitat type (Serena lodge, 2% cover at 3km). The other major river in the ecosystem, The Talek, flows through a ravine with lower water levels than Mara River and hence may have not been captured in the satellite image. Thick vegetation cover around water sources also explains their absence in the satellite image.

4.5.1.2 Distance to natural and anthropogenic features

Previous research indicates that as a result of the broad similarities in ungulate distributional patterns, dietary guilds, body size and foraging guilds have little influence on their distribution in relation to water sources or human settlements (Ogutu *et al.*, 2010). This supposition was supported by the 2002 Mara wildlife and livestock count which reported similar wildlife species abundance in both the protected reserve and the group ranches which act as wildlife dispersal zones (Ojwang' *et al.*, 2006). After overlaying the functional map layers, the spatial analysis toolset in ArcGIS (ESRI, 2011) were used to generate and display distance bands from the study sites to the nearest permanent water bodies (Figure 4.6), human settlements

(Figure 4.6) and major roads (Figure 4.8) to demonstrate their spatial relationships to the study sites.

i. Distance to permanent water bodies

Previous studies by Ogutu *et al.* (2010) and Serneels and Lambin (2001b) described accessibility to water sources as being critical in this ecosystem for both the local community, their livestock and wildlife. Temporary and seasonal rivers and springs were mapped and distance calculated as a series of 1 km buffers. As all the study sites were located in well-watered areas with permanent water sources within 1km radius, wildlife was assumed to be similarly distributed around them.

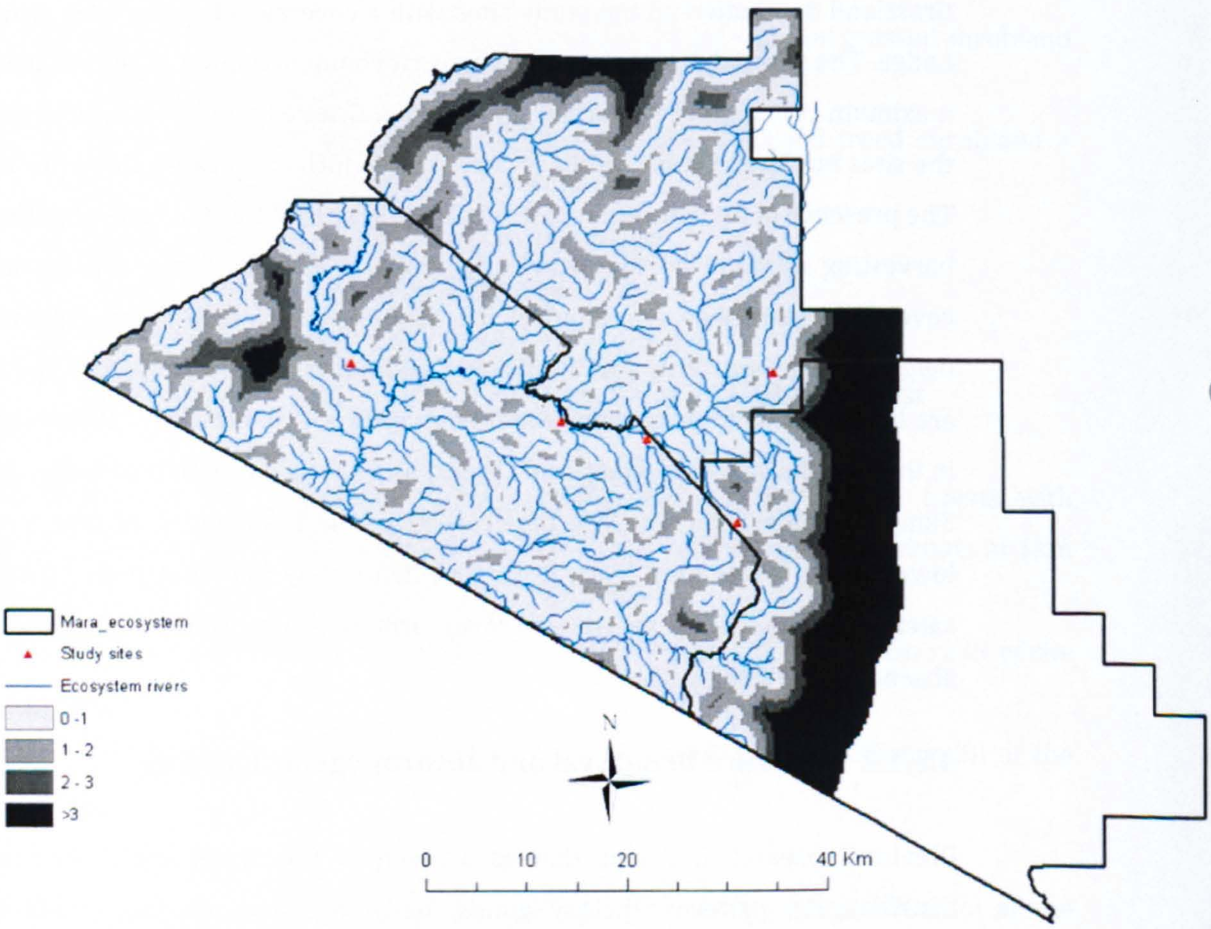

Figure 4.6 Distance to permanent rivers (km)

ii. Distance to human settlements

In the last decade, the human population in the Mara region increased by 24% (Kenya National Bureau of Statistics, 2010b) while pastoral settlements were recorded to have increased almost 23-fold over a 50 year period (Lamprey and Reid, 2004a) and are shown to be expanding closer to the national reserve than further away. This is most likely due to their being attracted by the enhanced economic activities and opportunities (Ogutu *et al.*, 2009) offered by the growing tourism industry inside and near the reserve.

Both livestock and wildlife share grazing and water resources in the Mara ecosystem and proximity to water has been highlighted as a critical determinant of settlement site selection (Ogutu *et al.*, 2010) with wildlife patterns demonstrating considerable plasticity from settlements. For this study distance to the nearest settlement was calculated by creating a series of 1 km buffers from each settlement. Figure 4.7 below shows the number of human settlements within 1km and 3km observation radii of the study sites. Mara Simba lodge had settlements within both 1km and 3km while Basecamp had a few settlements within 3km. Both these lodges are located very close to Talek centre, which has a high human density with several permanent private homesteads. Sekenani camp, located 6km from Sekenani centre, had a settlement within the 3km radius. This *manyatta* is also used as a cultural centre for tourist visits.

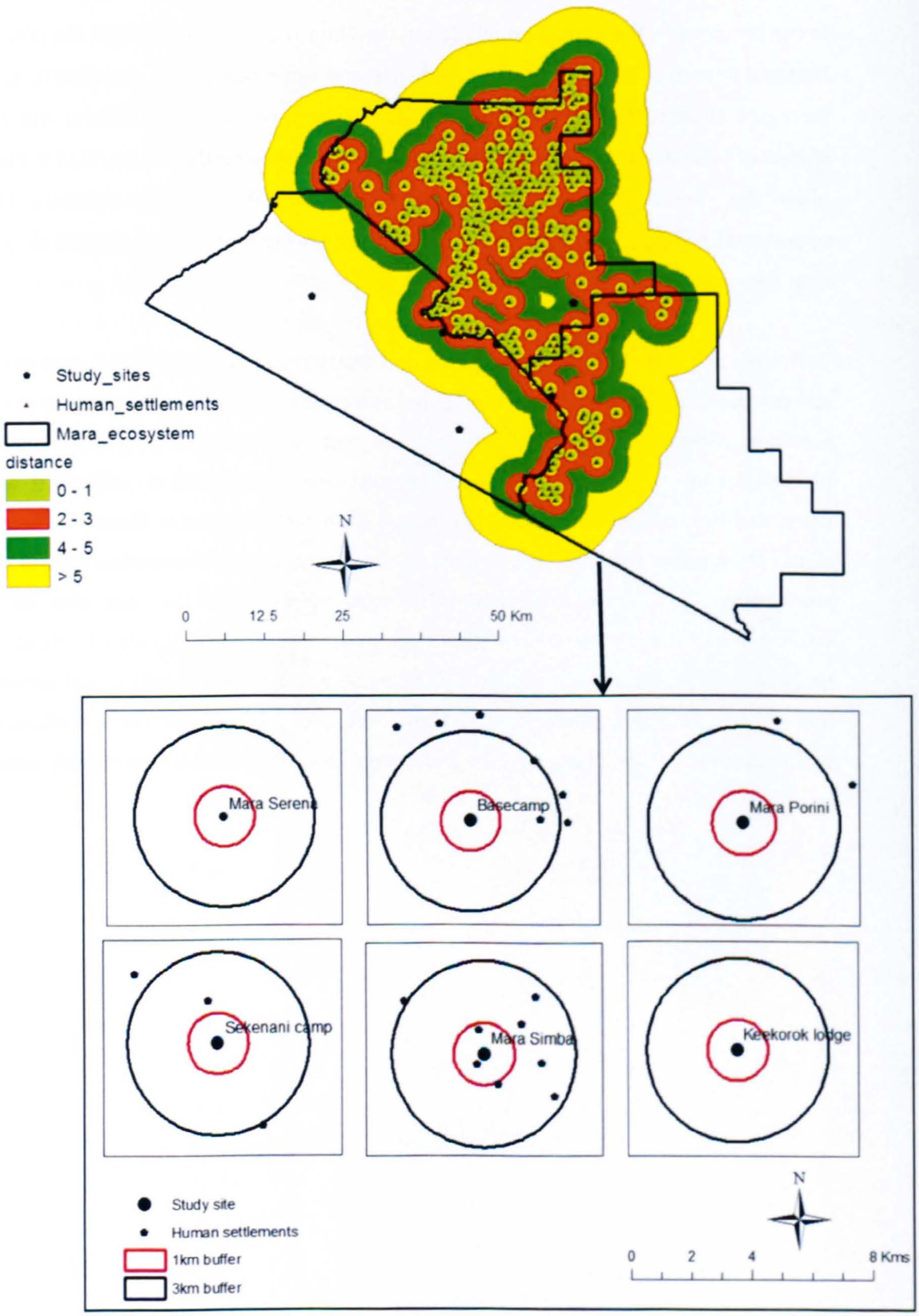

Figure 4.7 Distance to settlements (km) from the study sites

iii. Distance to major roads:

Roads have the potential to have a negative effect upon the distribution and behaviour of wildlife with impacts being viewed as either increased human access or as barriers to wildlife movement. The Mara Ecosystem has few official roads and viewing circuits, more so in the reserve. No tarmac roads exist in the reserve or the adjoining dispersal area reducing over speeding and the risk of wildlife accidents. A study on the impact of roads and off-road driving conducted in the Mara (Karanja, 2003) showed that although the number and location of roads and tracks as well as off-road driving disturbed the animals, they did not significantly affect their distribution. Major roads and study sites shape files were overlaid and Euclidean distance calculated by creating a series of buffers 1km from each arc of the ecosystem's road network to demonstrate the spatial relationship between the major road networks with the lodges. All the lodges were within near distance of the major roads in the ecosystem, which they use for access.

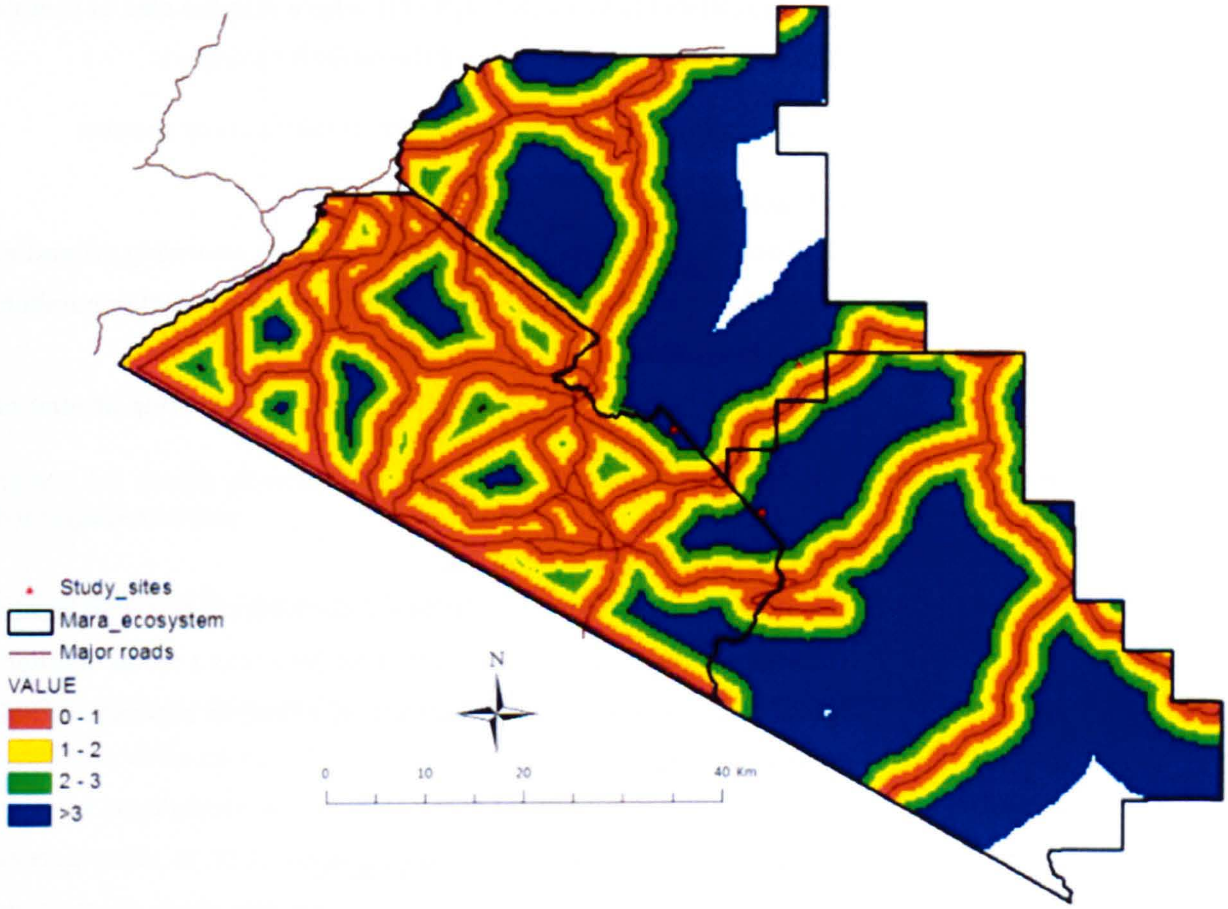

Figure 4.8 Distance to major roads (Km)

4.6 Results

4.6.1 Modelling framework

As the collected data were not normally distributed, a repeated measures ANOVA linear model run on the collected data returned inconclusive results. This was as a result of the model excluding from its analysis those study sites which did not include presence data for all twelve species during each of the four survey periods. In order to account for unequal sample size and incorporate all study sites with instances of species absence, the Kruskal-Wallis test (Kruskal and Wallis, 1952, Mc Donald, 2009), a repeated measures non-parametric linear model was run in SPSS (SPSS for Windows, 2009) to highlight any statistical significant differences in ungulate group size and distance between the different lodge types. A Bonferroni correction was applied to each of the models reduce the likelihood of type I errors.

$\mathbf{K = 12/(N(N+1)) \Sigma_{i=1..k} [R_i^2\text{-}3(N+1)]}$ where n_i is the size of sample i, N is the sum of the n_i and R_i is the sum of the ranks for sample i.

The following hypotheses were tested for each of the 12 study species;

a) Group size:

H_0: There is no difference in ungulate numbers occurring around eco-facilities and traditional lodges. Any noticeable difference in wildlife numbers is a result of other variables.

H_1: There is a difference in ungulate numbers occurring around eco-facilities and traditional lodges.

b) Distance to tourist development:

H_0: There is no difference in ungulate distribution between eco-facilities and traditional lodges - any observed differences are as a result of other variables.

H_1: There is a difference in ungulate distribution between eco-facilities and traditional lodges.

c) Seasonal influences on ungulate responses:

H_0: The different tourism seasons do not influence ungulate response to tourism developments.

H_1: The different tourism seasons influence ungulate response to tourism developments.

Species group size

The Kruskal-Wallis one-way ANOVA revealed no significant difference for species group size indicating that species numbers were not influenced by development type at 95% confidence levels (with Bonferroni correction). Only Buffalo (Figure 4.9) showed a statistically significant difference in group size (χ^2=7.998, df=1, p=0.005) between the different lodge types. Typically buffalo compete with cattle for pasture and prefer to be close to tourist facilities where the presence of cattle is controlled by lodge management.

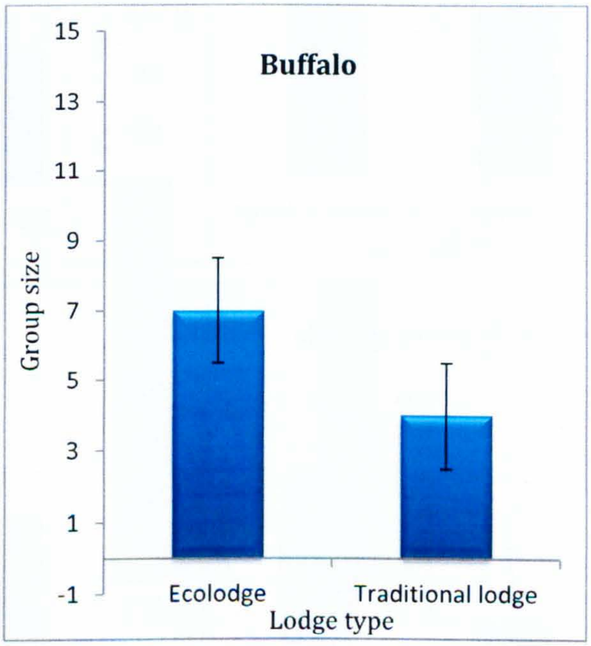

Figure 4.9 Graph showing significant difference in buffalo group size between development types

Species distance to tourist developments

Average species distance from the two lodge types were calculated and tested for significant differences. The Kruskal-Wallis one-way ANOVA test revealed varying levels of significance in wildlife presence around the different categories of tourist developments at 95% confidence levels (with Bonferroni correction), with higher tolerance by study species to eco-lodges noted (mean distance of 266.8m) than to traditional lodges (447.03m). Figure 4.10 below demonstrates the significant differences in distance to developments by; buffalo (χ^2=23.341, df=1, p=0.000) and topi (χ^2=19.173, df=1, p=0.000) which strongly compete for pasture with cattle; Thompson's gazelle (χ^2=25.996, df=1, p=0.000) and zebra (χ^2=5.559, df=1, p=0.018) which are strongly water dependent and may rely on the presence of permanent water bodies in the study sites.

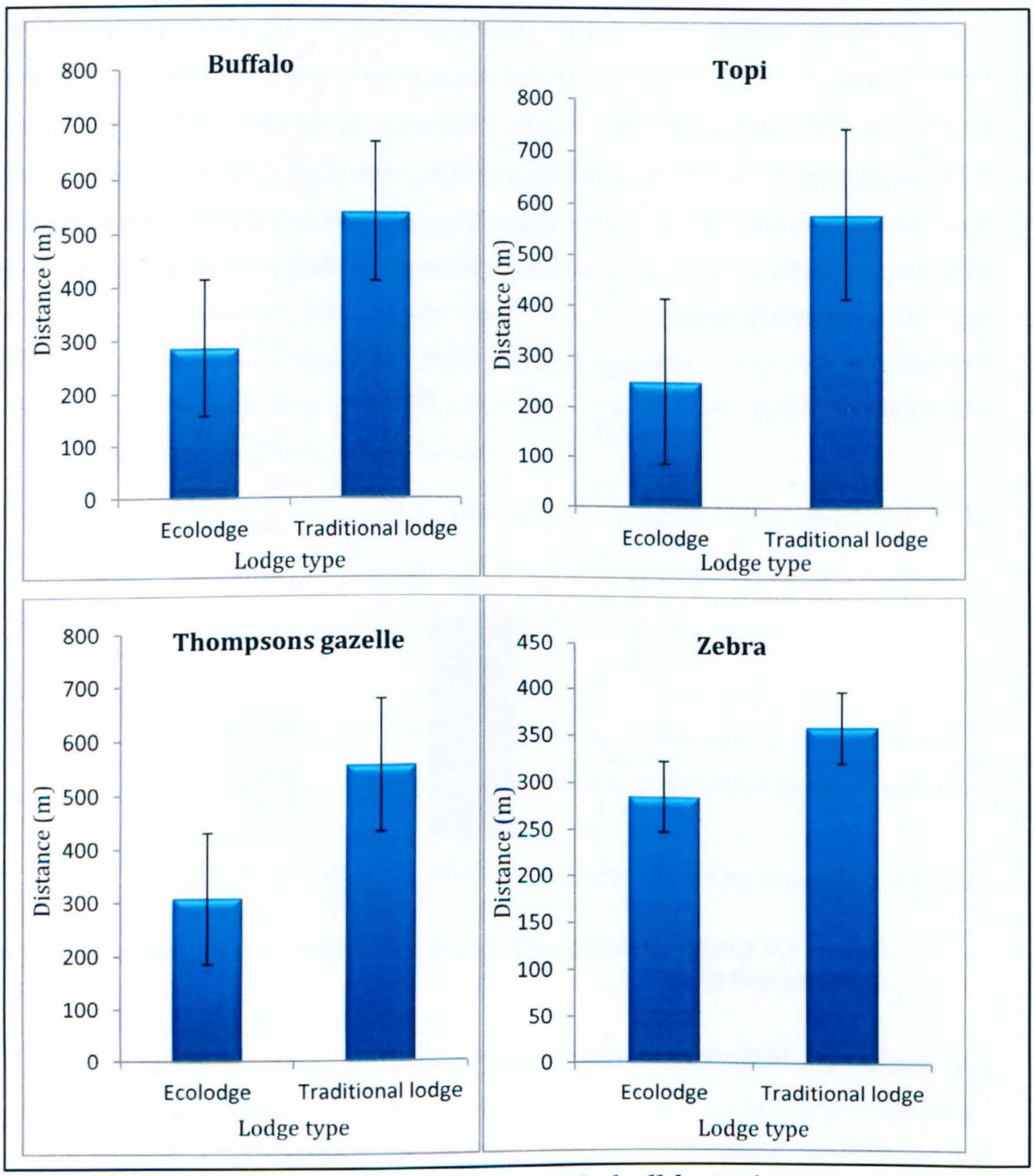

Figure 4.10 Graphs of significant differences in buffalo, topi, grants gazelle and zebra distances between development types

Seasonal variability in species response to tourist developments

There are two distinct tourism seasons in the Mara Ecosystem which determine visitor numbers which are measured by bed occupancy. Bed occupancy in the Mara has been recorded as being at its highest between July and September during the dry season and wildebeest migration from Serengeti that also coincides with the European and American holiday season. Occupancy is lowest between March and April during the long rains (Karanja, 2003). It was hypothesised that impacts to ungulates were higher during the high tourism season when there was more disturbance in the ecosystem from tourists.

The Kruskal-Wallis one-way ANOVA indicated a significant difference in topi (χ^2=5.391, df=1, p=0.020) and Grant's gazelle (χ^2=3.915, df=1, p=0.048) group size across the two tourism seasons with Grant's gazelle only recorded around ecolodges (Figure 4.11). Densities of the other study species were not significantly affected by tourism season (p<0.025).

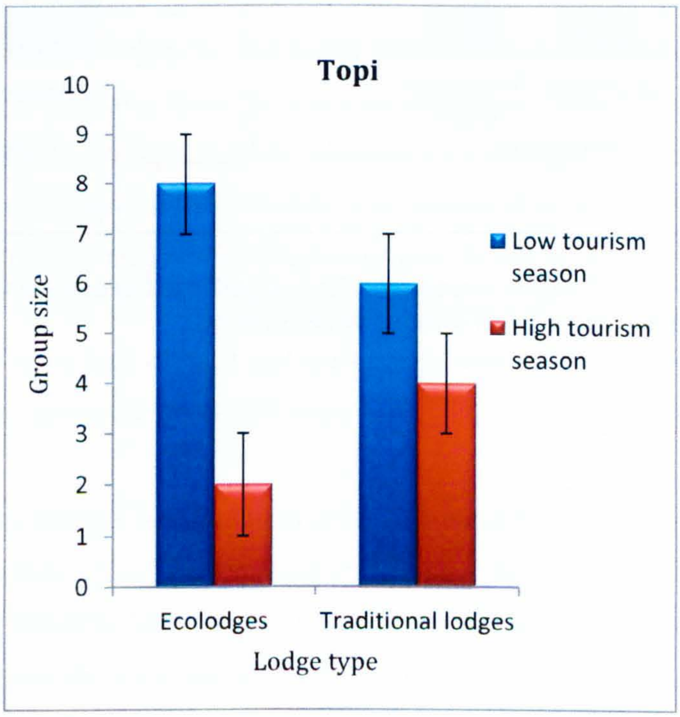

Figure 4.11 Graph demonstrating significant seasonal variability in topi group size around tourist developments

Buffalo (χ^2=5.040, df=1, p=0.025) and Impala (χ^2=5.090, df=1, p=0.024) demonstrated significant differences in distance from the tourist lodges across the tourism seasons (Figure 4.12) with the remaining study species not significantly influenced by seasonal differences (p<0.025).

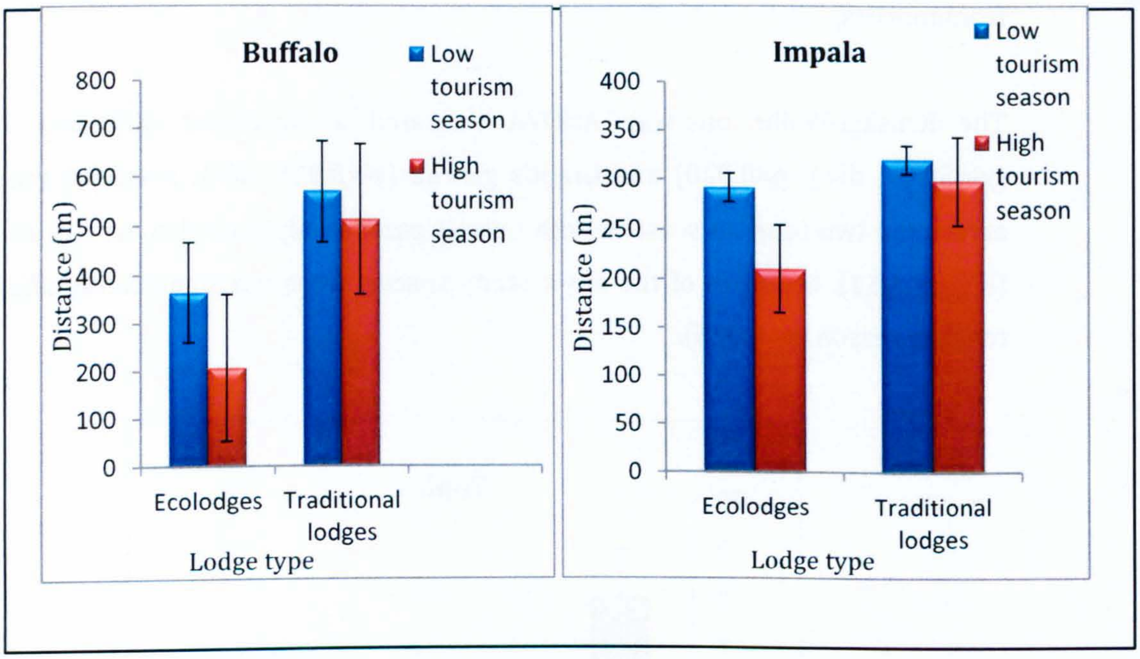

Figure 4.12 Graphs demonstrating significant seasonal variability in buffalo and impala distance from tourist developments

4.7 Discussion

The results of this study indicate that although ecotourism plays an important role in environmental conservation through its preference for small scale-low impact construction, its utilisation of locally available materials and a major interest in waste minimisation and recycling (Southgate, 2006), its ecological impacts on local wildlife species in receiving environments is still significant.

During the course of this study, it was observed that all wildlife species are affected by the presence of developments and human activity in one way or other. The effects of tourism and tourist activities on wildlife appear to be species specific (Hidinger, 1999) with species that have long coexistence with humans thriving in developed areas while other species tend to be displaced as a result of habitat loss or modification (Theobald *et al.*, 1997) whereas others show no apparent difference. Some of the study species were noted to have on average a higher tolerance to eco-lodges than traditional lodges which may in part be due to the non-intrusive nature of ecotourism. However, their numbers per group and frequency of sightings greatly varied across the development types, with only buffalo showing a significant difference in group size between lodge types as a result of its high dietary and water requirements which are more available around the lodges inside the protected area.

As wildlife species become habituated to areas of human presence, they begin to utilize these areas as "safety zones" from predators, which avoid human disturbance (Alessa et al., 2007). The resulting high or low species densities in these tourist areas can alter ecological processes, for instance long-term changes in the floristic makeup of these areas due to changes in herbivore populations (Hidinger, 1999). In cases where detectability of a species at a particular site is not random but is instead related to habitat characteristics, suitability models derived from these data may overstate the importance of those habitat variables that are positively related to detection probability (Gu and Swihart, 2003) which could negatively influence management decisions.

In recent years, land use changes in the Mara Ecosystem have resulted in those areas set aside for wildlife tourism becoming isolated patches within a matrix of other land uses thus leading to a rise in cases of human-wildlife conflict which have an impact on ungulate populations. Though it was not possible to include the impacts of land privatisation and expansion of large scale mechanized agriculture into this study, it is recognized that they have a major influence on wildlife density and distribution patterns in the Mara Ecosystem. The regular grazing of cattle in the national reserve along most of its eastern and northern boundaries has increased competition with wildlife especially long grass feeders like the topi (Ogutu *et al.*, 2009). This competition for pasture between livestock and herbivores is intensified during periods of drought causing over grazing and delaying natural vegetation regeneration after the drought. Buffalo are most affected by drought with population reductions of 70% recorded after the drought of 1993 (Sinclair *et al.*, 2008). In the second half of 2009, Kenya experienced a severe drought which had a negative influence on wildlife populations through reduced reproductive and survival rates, resulting from low and limited forage. This may have been an influencing factor in the observed close association of larger herbivores (like buffalo) with developments which are located in well watered areas with lower competition for forage with livestock.

This element of the research focused on wildlife response to tourist facilities, but was confined to six areas of developments in the ecosystem, with only relatively few members of a population observed. Kerbiriou *et al.* (2009) suggests the use of "a population dynamics model to project the influence of human disturbance on present and future population viability under different scenarios of tourism development." Future work should therefore look into investigating wildlife response and changes in population as a result of increasing human disturbances with species data collected from all sources of disturbance within a protected area.

Chapter 5

LONG TERM UNGULATE SPATIAL RESPONSE IN A CHANGING LANDSCAPE

5.1 Introduction

The most serious long-term threat to the future of wildlife populations in Kenya is the indirect effects on their habitat resource through destruction or alteration (Lado, 1992). In the Mara Ecosystem, habitat fragmentation mainly caused by the conversion of privately owned rangelands to agriculture and ranching is of great concern to wildlife managers (Ottichilo *et al.*, 2000). Ogutu *et al.*, (2009) lists rapid human population growth and expansion of settlements as other major threats to the long term viability of wildlife in the Mara region. These threats coupled with habitat alteration and increasing competition between wildlife and livestock have resulted in marked declines in wildlife numbers. Land use changes in the Mara Ecosystem resulting in habitat fragmentation and the loss of wildlife wet season range in the Loita plains have been said to have a much wider impact on the dynamics of the ecosystem's wild ungulates than the effects of climatic variations (Said, 2003).

Previous research on the impacts of tourism on wildlife in the Mara Ecosystem by Karanja (2003) focused on the impacts of tourist vehicles on the distribution and behaviour of common herbivores, describing vehicle impact on wildlife as limited to short-term disturbance which increased with higher speeds. This author further noted that tourism pressure in the ecosystem did not adversely affect herbivore distribution within the MMNR, and habituation in heavily visited areas limited the amount of disturbance. This study has focused on the impacts that the increasing tourist accommodation facilities have on the density and distribution of ungulate species in the Mara and used a GIS to demonstrate patterns of change. Oindo (2003) describes mapping species richness and distribution as an important aspect of conservation and land use planning, adding that maps help identify areas of special biodiversity importance where conservation resources should be focused. Such areas include species 'hot spots' which may be locations of species richness, arrived at by one of several standard measures, or where species assemblages occur. At the time of writing, such maps do not exist for the Mara Ecosystem, save for those presented here.

5.2 Research questions

i. What are the temporal and spatial changes in the twelve study species over the twenty year period between 1990 and 2010 in the Mara Ecosystem?

ii. How has tourism growth affected the distribution of ungulates in the Mara Ecosystem within that time period?

5.3 Methodology

Since 1977, the Kenya Rangeland Ecological Monitoring Unit, later renamed the Department of Resource Surveys and Remote Sensing (DRSRS) have carried out regular aerial surveys of wildlife and livestock throughout the rangelands in collaboration with various international, private and governmental agencies (Ojwang' *et al.*, 2006). For this research, data were provided by them from the dry season censuses of large herbivores conducted in the Mara ecosystem between 1990 and 2010. Only post-1990 surveys were used for this study as previous surveys were methodologically inconsistent and subject to unrealistic variations (Khaemba and Stein, 2000).

Typically, aerial surveys simultaneously observe and record several wildlife and livestock species. The aerial census data collected by DRSRS used the systematic reconnaissance flight (SRF) method as described by Norton-Griffiths (1978). A number of pre-determined transects oriented in an east-west or north–south directions were systematically flown at 5km intervals at a flight height of 122 meters and strip width of approximately 282 meters. All the censuses were surveyed at a 5 x 5 km sampling resolution using high-wing aircraft (Cessna 185 or Partinvia) equipped with GPS at flight. These censuses are designed to cover a sampling fraction of between 3.5% and 11.8% for the Mara Ecosystem. Experienced and well trained observers occupied the rear and front sections of the aircraft and counted and recorded all animals falling within the strip width into tape recorders. Oblique photographs of animal herds containing more than ten animals were taken using a 35mm camera and later projected onto a screen and counted for correction of visual estimates (Ojwang' *et al.*, 2006, Khaemba and Stein, 2000, Ogutu *et al.*, 2011).

During their counts, DRSRS treated each 5 km transect as an observation and any animals counted were spatially recorded within the Universal Transverse Mercator (UTM) grid to the nearest 25 km^2. They calculated Population estimates (PE) and standard errors (SE) using a modification of Jolly's method 1 (Jolly 1969 cited in (Stelfox *et al.*, 1986), where PE was estimated as:

$$\mathbf{PE = N\tilde{y}} \quad \text{and } \mathbf{SE = \sqrt{N}\,(N\text{-}n)\,s^2/n}$$

where $\tilde{y}$ is the sample mean, s^2 is the sample variance, n is the sample size and N is the number of observations required to completely cover the study area.

Empirical tests of visibility bias in the Mara ecosystem indicated counting efficiency of 70-80% of wild herbivores and 80-90% for livestock. Count totals were therefore corrected upward by about 1.33x for wildlife and 1.18x for livestock (Stelfox *et al.*, 1986, Ogutu *et al.*, 2011). To calculate kernel densities for each study species for each survey year, the number of animals counted in each grid squares was used as a weighting factor to determine kernel densities for study species

In order to create the necessary baseline map to examine patterns in the development and capacity of tourist accommodation facilities in the Mara Ecosystem, numerous physical visits to tourist developments and interviewing lodge managers were undertaken. The facilities were geo-referenced with bed capacities, year of establishment and development type recorded and converted to shape files in ArcGIS 10 (Figure 3.7). Once the historical and current datasets were in place, functional layers were created to visualise and analyse the relevant topographical data.

5.4 Data Analysis

Major decline of wildlife populations in the Mara Ecosystem have been documented for the past twenty years with giraffe, eland, warthog and waterbuck in particular recording significant decline in numbers (Homewood *et al.*, 2001, Lamprey and Reid, 2004b, Ottichilo *et al.*, 2000, Ogutu *et al.*, 2009). Most of these declines have been attributed to land use changes in the ecosystem coupled with a rapidly growing human population, expansion of agriculture and progressive habitat deterioration (Serneels and Lambin, 2001a, Ogutu *et al.*, 2009). This research hypothesized that the expansion of tourism in the Mara Ecosystem has also had significant impacts on its ungulate populations.

To examine these changes in species density and distribution in the study area over a twenty year period, density maps were used to visualise species distribution across landscapes using count data to produce kernel density maps. The kernel method of mapping makes a count of the number of data elements in a radius surrounding each grid cell and applies a probability function to generate a smoothly tapered surface at each point and between adjacent grid cells producing a density value of number of events (animals) per square kilometre (ESRI, 2001). Kernel density estimates are currently the most popular statistical approach to characterising and visualizing species home ranges (John G. Kie et al., 2010), with their outputs reflecting the areas of concentration (hotspots) in mapped areas.

Kernel density maps were created in a Geographical Information System (GIS) from aerial count data sourced from the DRSRS. 5-yearly interval datasets for the years 1990, 1996, 2000, 2005 and 2010 were used in this study, but owing to lack of resources in 1995, the aerial census was not conducted and the 1996 dataset was instead used. To generate kernel density maps, species count data for each year was loaded in ArcMap and converted to point layer maps. Once the layers were in place, kernel density analysis was carried out using the density function located in the spatial analyst toolbox using the following set of commands:

- Input layer = created species count layer map
- population field = species point attributes which acts as the weighting factor for number of animals counted

- Output raster size = 2500m ($0.25km^2$) grid (A raster consists of a matrix of cells or pixels organised into grids where each cell contains a value representing information for the area covered by that cell, such as temperature, land use and elevation data (ESRI, 2011).)
- Search radius = 1000m (1km)
- Area units = square kilometres (km^2)

The increasing growth in tourism was also spatially demonstrated as an additional layer in the density maps (Fig 5.1) to be related to changes in distribution and density patterns of the study species over the twenty year period between 1990 and 2010.

5.5 Results

5.5.1 Growth of tourism developments in the Mara Ecosystem

A major element of this research was to examine the changes in species distribution and density in response to increasing tourism development in the Mara Ecosystem. Previous chapters in this thesis (Chapters 1 and 3) have described in detail the growth of tourism in Kenya and specifically this ecosystem. The fast growth of tourism outside the reserve, particularly evident since 2005 (Figure 5.1), is a result of the subdivision of former trust land into private leaseholds with new landlords opting to lease their land to tourism investors. The mushrooming of facilities is especially evident in Sekenani, Talek and Oloolaimutia areas which are adjacent to the National Reserve gates and also house growing permanent residential and commercial settlements. Since 2005, several facilities have been constructed inside the National Reserve along the Mara River, popular for wildebeest crossings during the migration season, raising concerns over their impacts on the migrating wildlife. Research on the Mara River basin has suggested that the high number of tourist developments along Mara River may be partly responsible for its poor condition due to water abstraction by the lodges and camps for their daily requirements and increased pollution as some of these developments lack facilities for solid waste disposal or waste water treatment (LVBC & WWF-ESARPO, 2010). Furthermore, the area around Sand River close to the Kenya-Tanzania border, once considered a wilderness area, faces a similar situation with new facilities being constructed (personal observation).

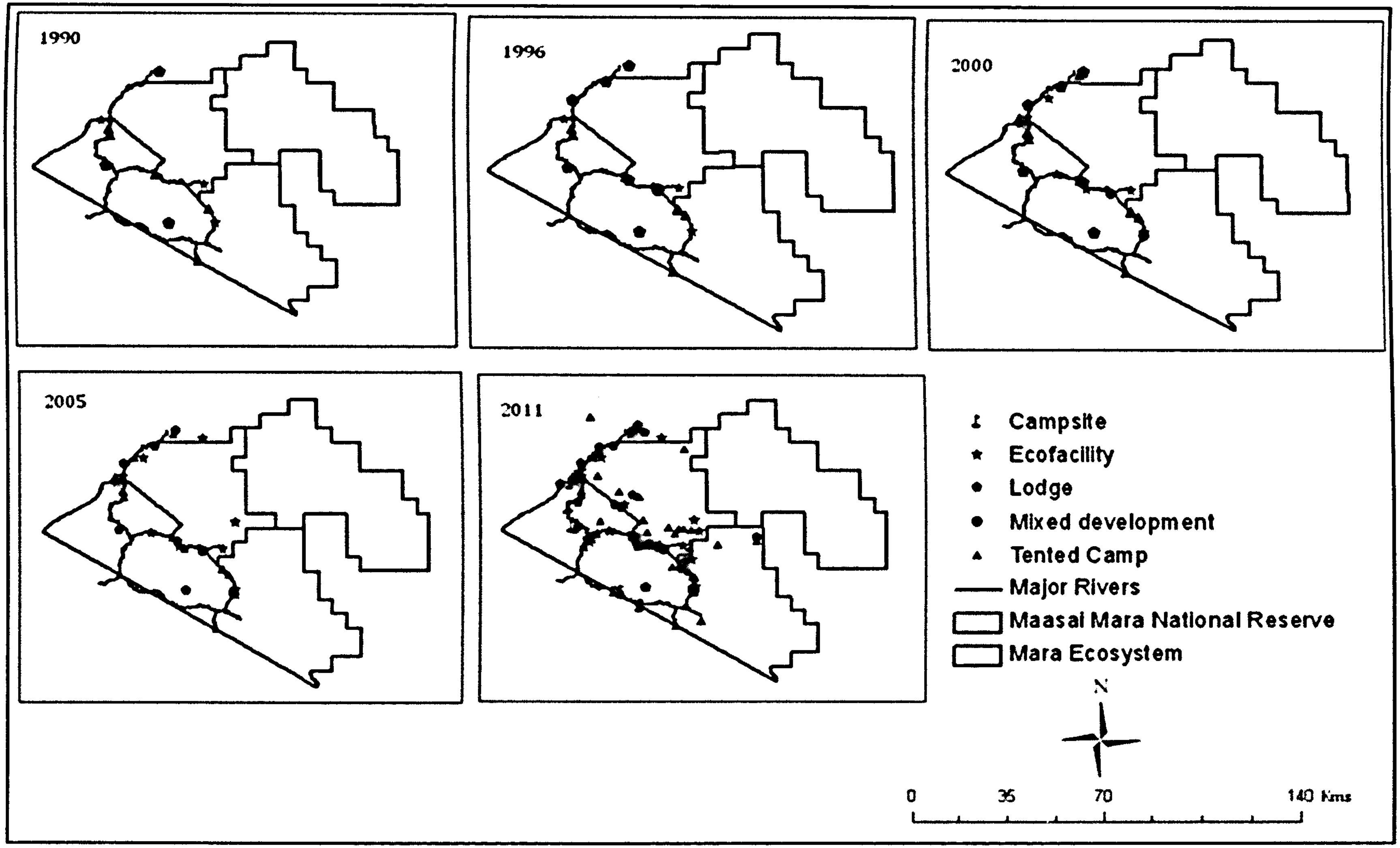

Figure 5.1 Maps showing location and increase of tourist facilities (by type) in the Mara Ecosystem

5.5.2 Changes in wildlife density and distribution in the Mara Ecosystem

Density maps (Fig 5.3a –5.3l) were created for each study species for each survey year (1990, 1996, 2000, 2005 and 2010) to demonstrate variation in their distribution and densities in the ecosystem in relation to tourist facilities. Kernel density estimation (KDE) is an established and robust application of hotspot mapping of observed phenomena (Alessa et al., 2007). It uses a quartic algorithm (see below) to transform species point data into a continuous surface which provides a representation of species' distribution and allows for easier identification of their hotspots.

$[1-(1/h)^2]^2, r/h<1$ Where r is cell radius and h is the bandwidth or smoothing factor

To identify species hotspots, a search radius of 1000m (1km) was defined to produce a search area of 1km^2 with the highest values computed at each species observation location, decreasing with increasing distance reaching 0 at the extent of the specified search distance. For this study, species hotspot areas were identified as the upper range of the kernel index range (coloured red in the species density and distribution maps (Fig 5.2a-5.2l). Species density estimates (number of animals per km^2) were calculated for each species by dividing the estimated population as provided by DRSRS by the areas of the Maasai Mara National Reserve and the ranches (Table 5.1).

The species density maps displayed species "hotspots" (high density areas) and their spatial variation over the twenty year period. On average, the north western section of the ecosystem revealed higher species densities than the south eastern section, with the Siana and Loita sections of the ecosystem showing the greatest reduction in hotspots. The changes in density in the two sections are a result of the high number of tourist facilities and permanent human settlements present in Siana and increased wheat farming in the Loita plains, which have subsequently taken over historical wildlife ranges (Homewood et al., 2001, Honey, 2009, Mundia and Murayama, 2009).

Long severe droughts were experienced in Kenya in 1999 (Reid *et al.*, 2003) and 2009 reducing both livestock and wildlife numbers in the ecosystem, which subsequently influenced their densities in the following years (2000 and 2010). Several key patterns emerge over this time period. Grant's and Thompson's gazelles did not show major changes in their spatial hotspots over the twenty years and were well distributed in both the ranches and the reserve. The ability of zebra to thrive on bulky and low quality forage makes them widespread in the ecosystem. In the time period between 1996 and 2005, they had similar distribution and density hotspots with a preference for areas closer to the reserve and the Mara plains. The 2000 impala density map shows high densities around the Koiyaki area (in the Mara Plains) however, increasing tourism developments especially around Talek centre, has resulted in fewer hotspots in the ranches in later years. Topi distributions were noted to gradually edge closer to the protected area away from the ranches and the built up areas during the twenty year period. This change in distribution is consistent with increased tourism developments in the Sekenani and Talek areas (see Fig 5.2h). As specialised grazers, Topi prefer short to medium-height pastures (Kingdon, 1997) and are in direct competition with livestock in the ranches.

By 2010, most species hotspots had moved away from areas with high tourist facilities with waterbuck, eland and giraffe displaying the greatest spatial change in their hotspot distribution. Buffalo density hotspots were consistently within or adjacent to the national reserve where competition for pasture with livestock was at a minimum. Buffalo are considered conservation dependent, with the Food and Agriculture Organisation predicting that in the next 20 years, 95% of their population will be restricted to protected areas (Food and Agriculture Organisation, 2011), a trend that is already evident in the Mara Ecosystem. Eland concentration shifted away from the heavily human populated areas of the ecosystem towards the southern end of the reserve which has fewer tourist facilities. However, the 2010 eland density map revealed its reappearance in the group ranches, in an area with a private wildlife conservancy (established in 2005) with controlled cattle grazing and no human settlements, highlighting the importance of increasing space for wildlife.

Warthog density maps showed distribution reduction over the twenty years with their hotspot areas confined to the triangle section of the National Reserve. This may be due to increased predation within the reserve and probable killings in the ranches as a result of poaching (Ogutu et al., 2009). The waterbuck maps demonstrate their range is restricted to the protected area where there are permanent water sources and no competition for forage with livestock. It is expected that as most tourist facilities are located close to permanent water bodies, waterbuck densities and distribution would be higher in these areas. However, the maps indicate a direct conflict between waterbuck and developments with hotspots located away from tourist facilities in the least developed sections of the reserve. With increasing tourist facilities in the reserve, waterbuck range is predicted to further reduce, reaffirmed in the 2010 count where the number of waterbuck recorded during the aerial survey was too low for the kernel density estimation algorithm in GIS to compute its distribution and density. The giraffe maps showed it distributed in both the protected area and ranches in the *Acacia* woodlands, its preferred habitat. With increased settlements and tourist facility construction in these areas over the years, there was a reduction in its range with hotspots outside the reserve found in the new wildlife conservancies.

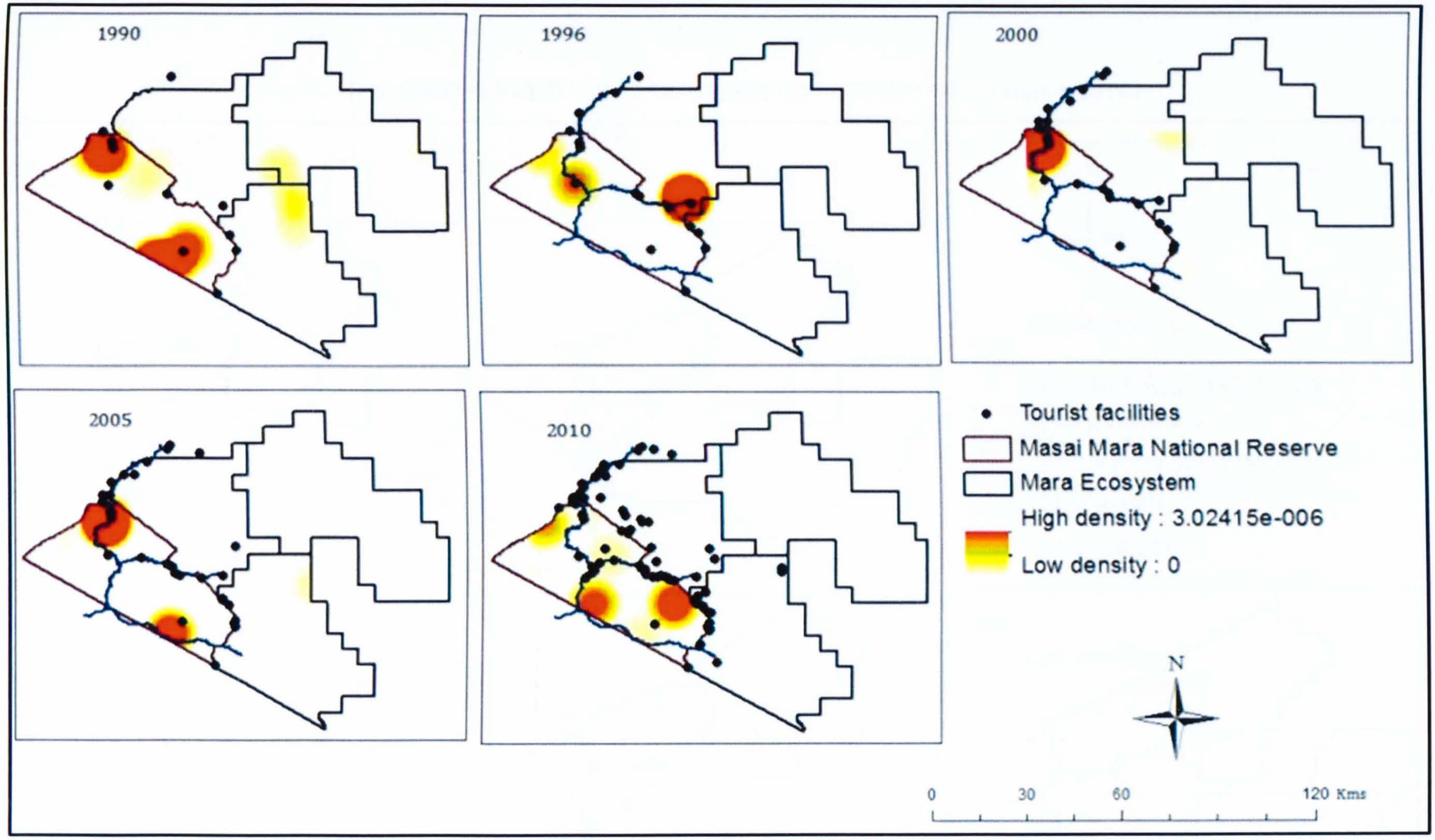

Figure 5.2a Density and distribution of Buffalo *(Syncerus caffer)* (1990 – 2010)

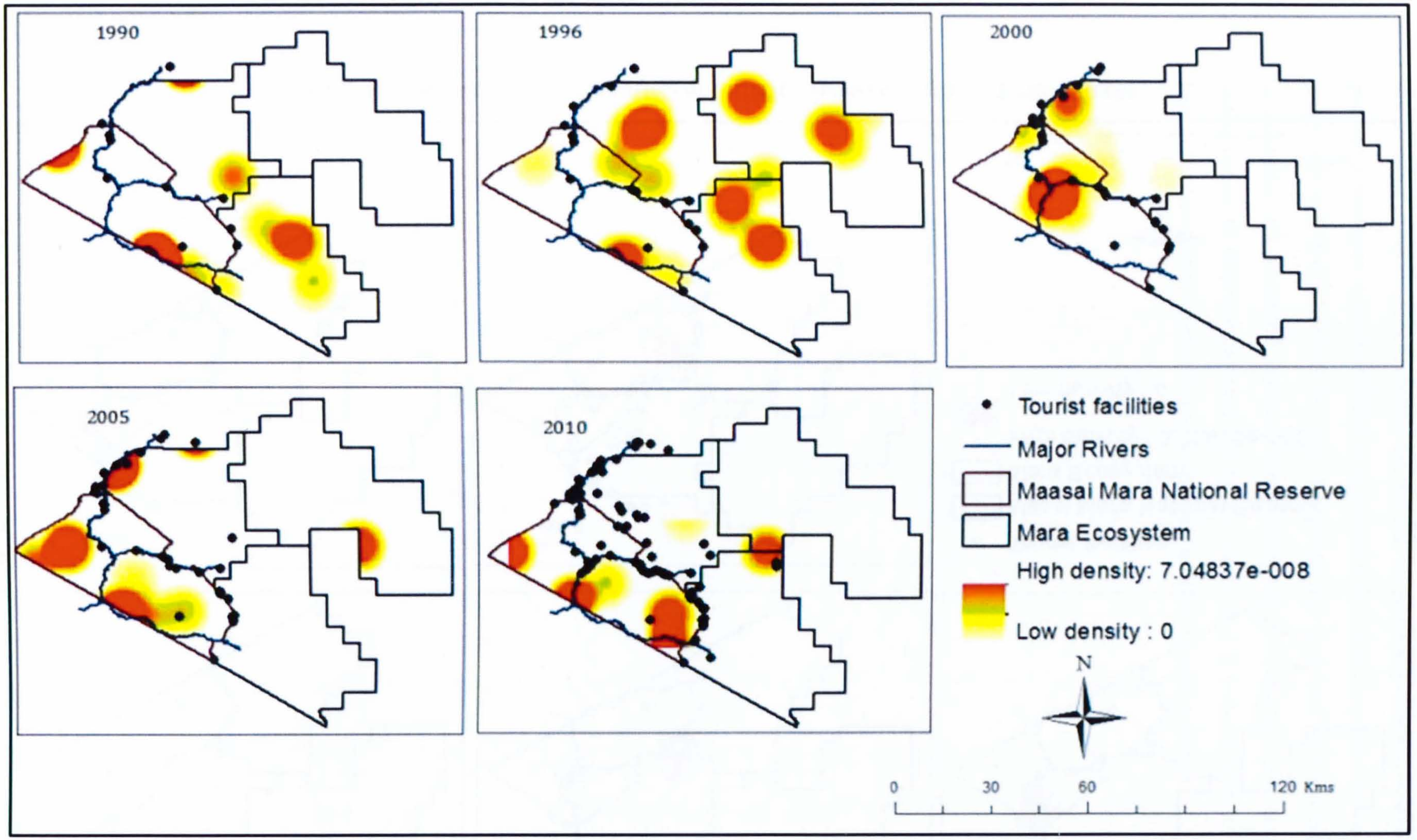

Figure 5.2b Density and distribution of Eland *(Taurotragus oryx)* (1990 – 2010)

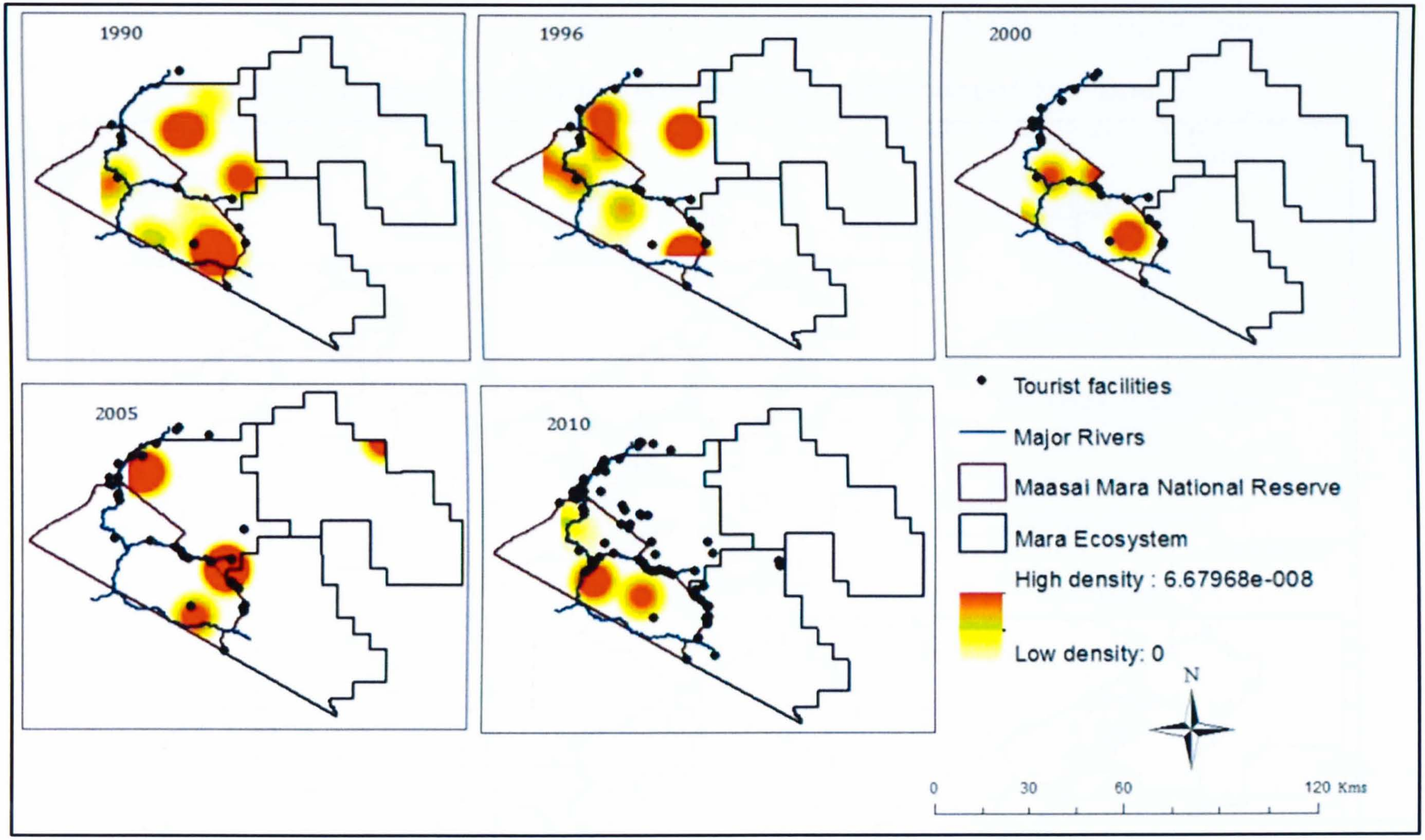

Figure 5.2c Density and distribution of Elephant *(Loxodonta africana)* (1990 – 2010)

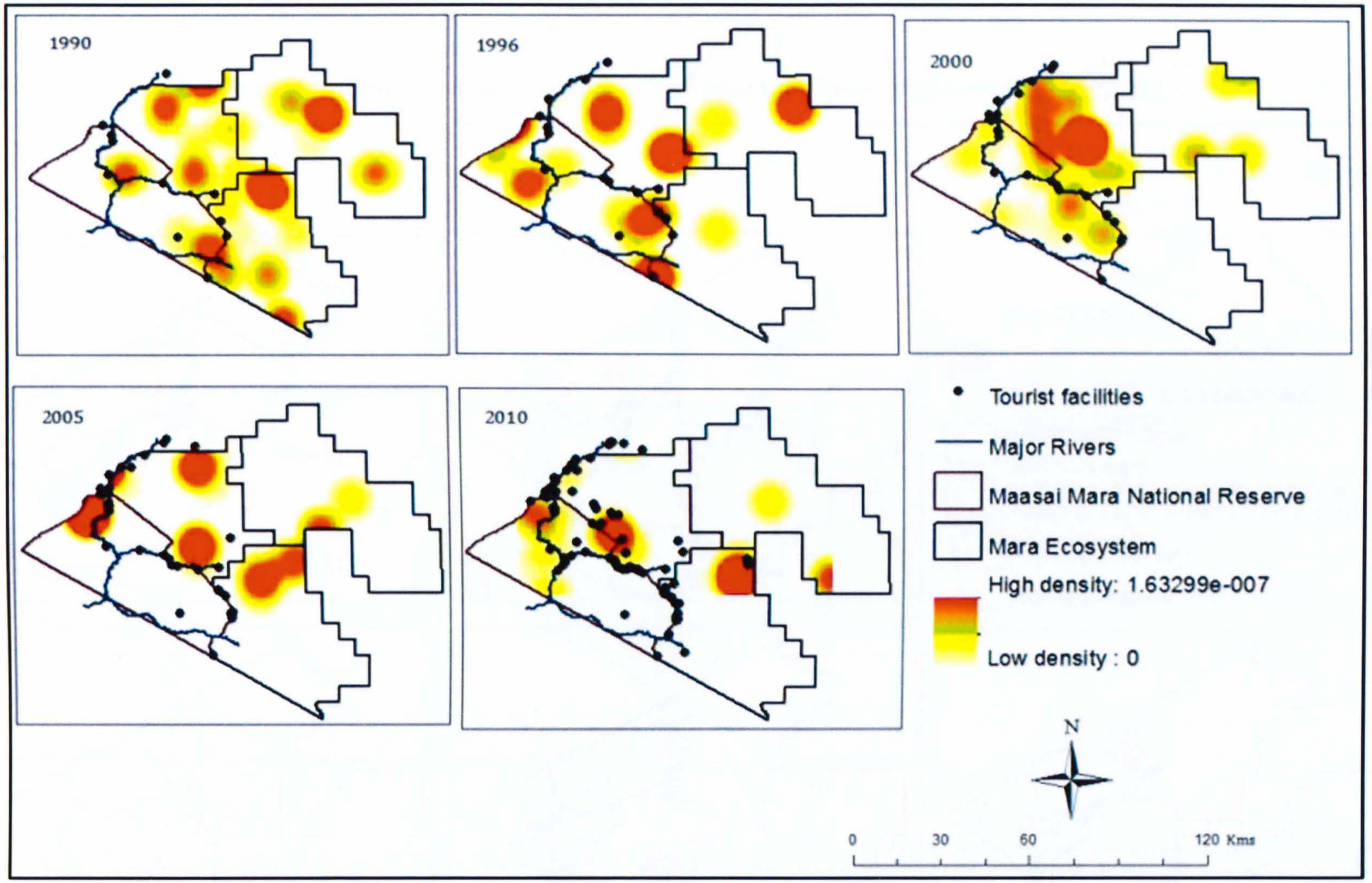

Figure 5.2d Density and distribution of Giraffe (*Giraffa camelopardalis*) (1990 – 2010)

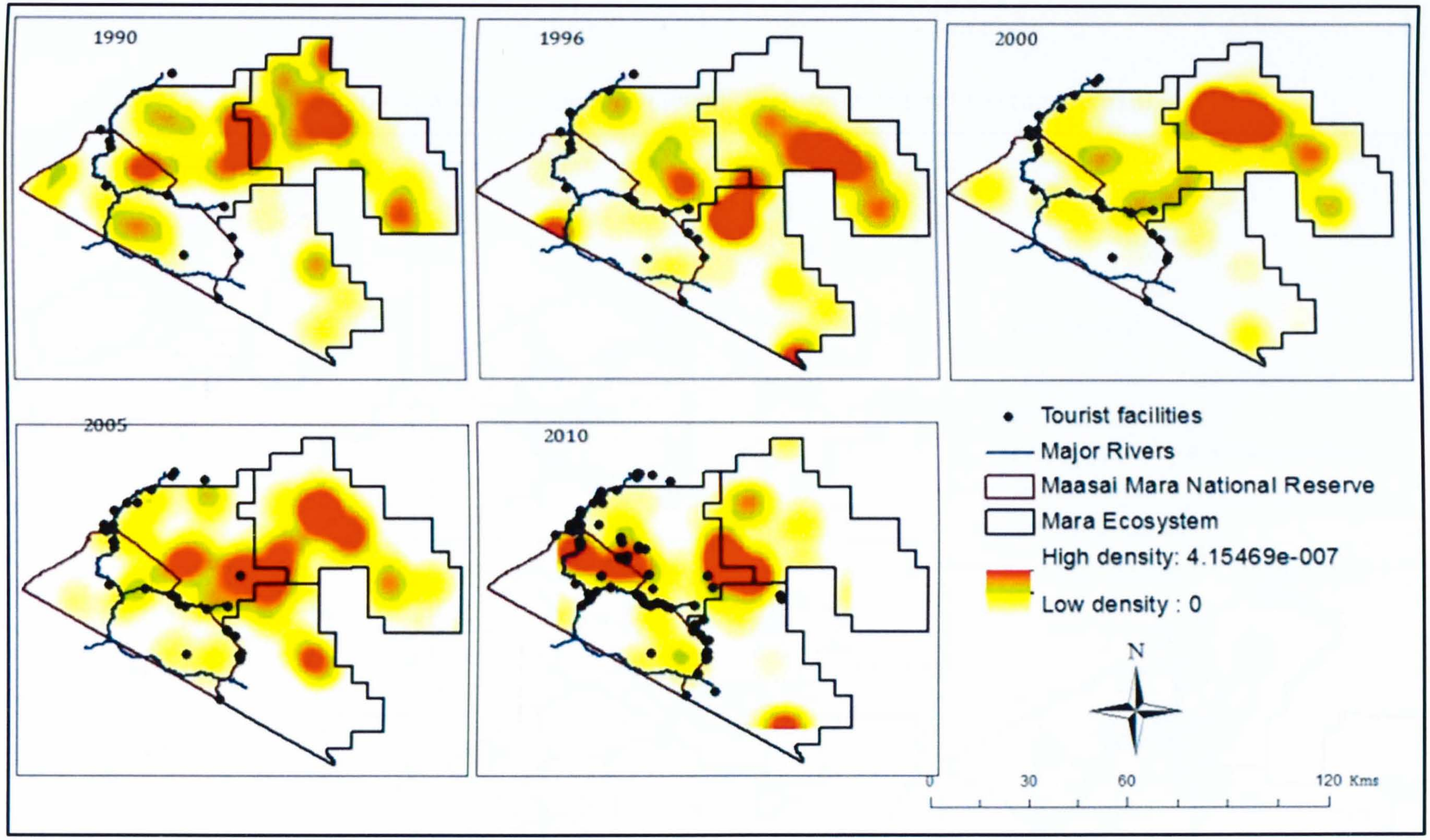

Figure 5.2e Density and distribution of Grant's Gazelle (*Gazella granti*) (1990 – 2010)

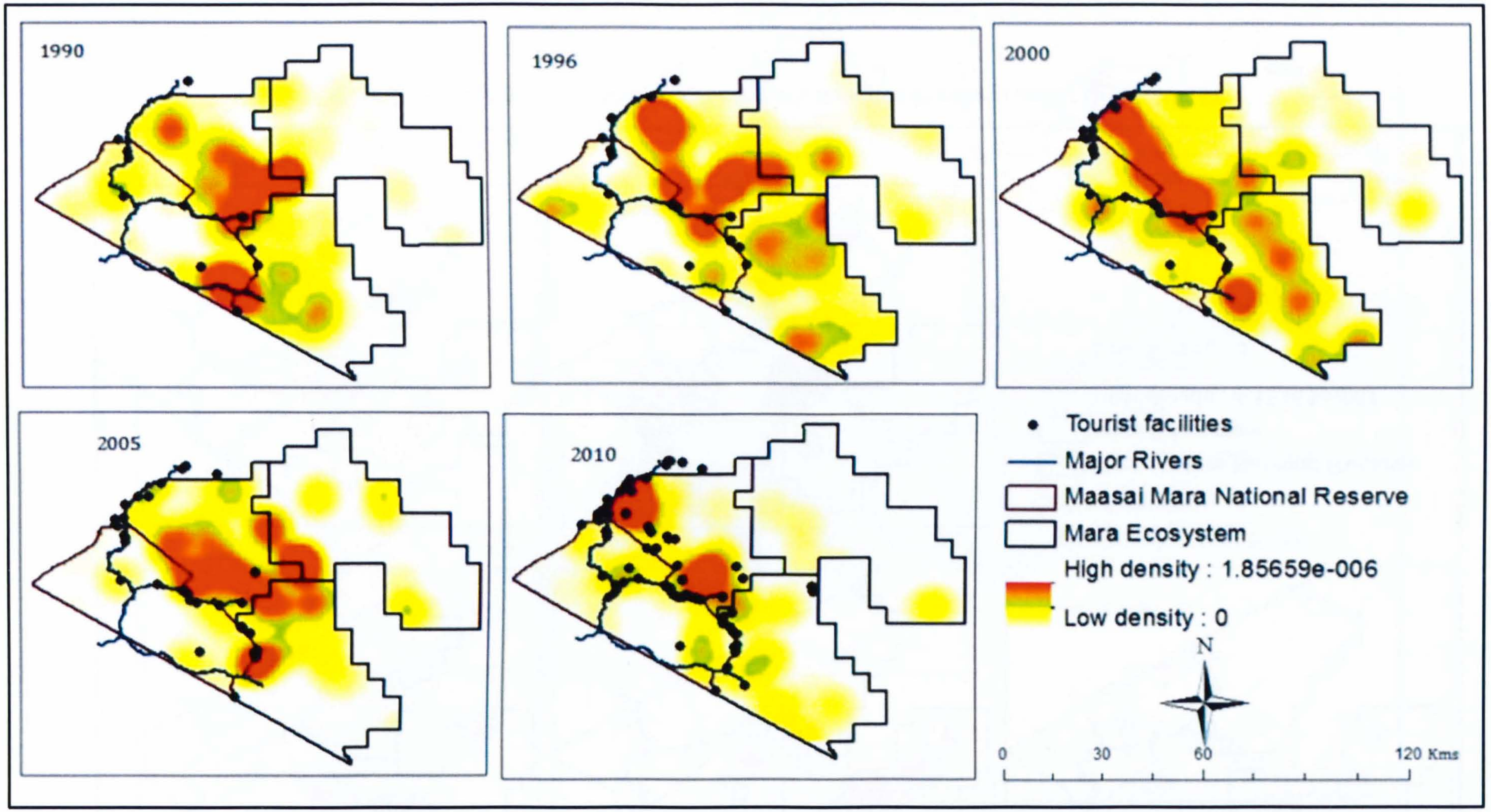

Figure 5.2f Density and distribution of Impala (*Aepyceros melampus*) (1990 – 2010)

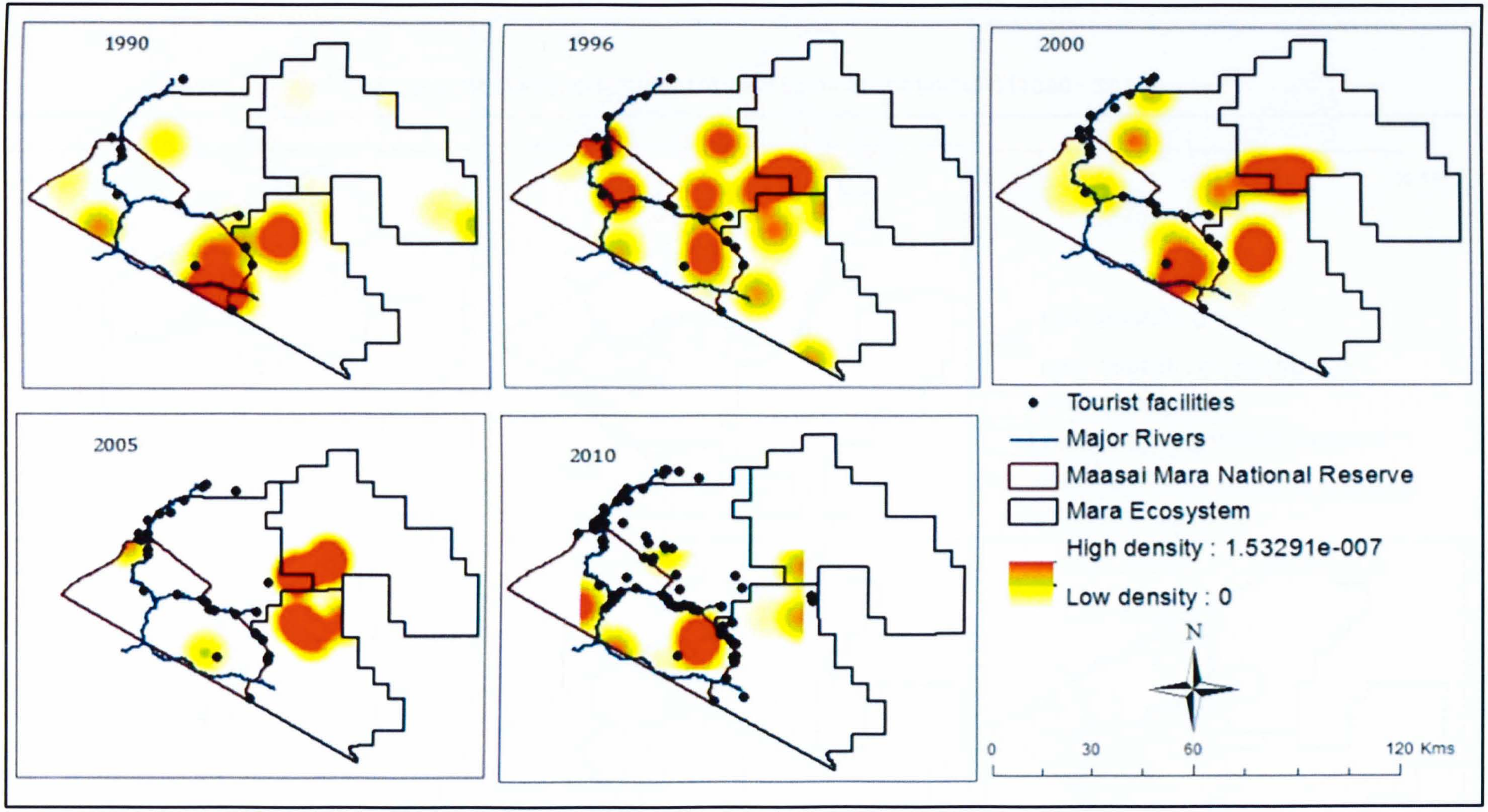

Figure 5.2g Density and distribution of Kongoni (*Alcelaphus buselaphus*) (1990 – 2010)

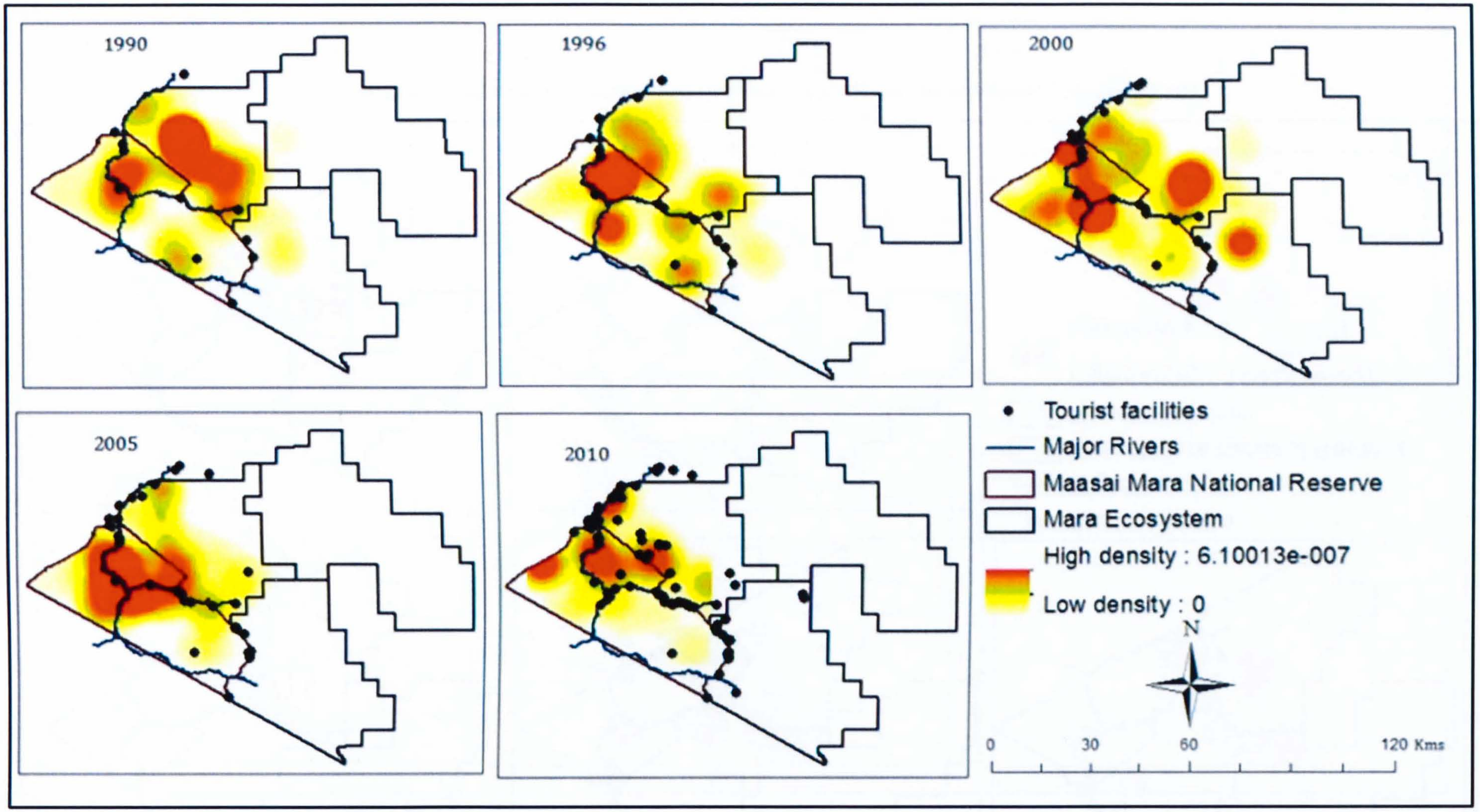

Figure 5.2h Density and distribution of Topi (*Damaliscus lunatus*) (1990 – 2010)

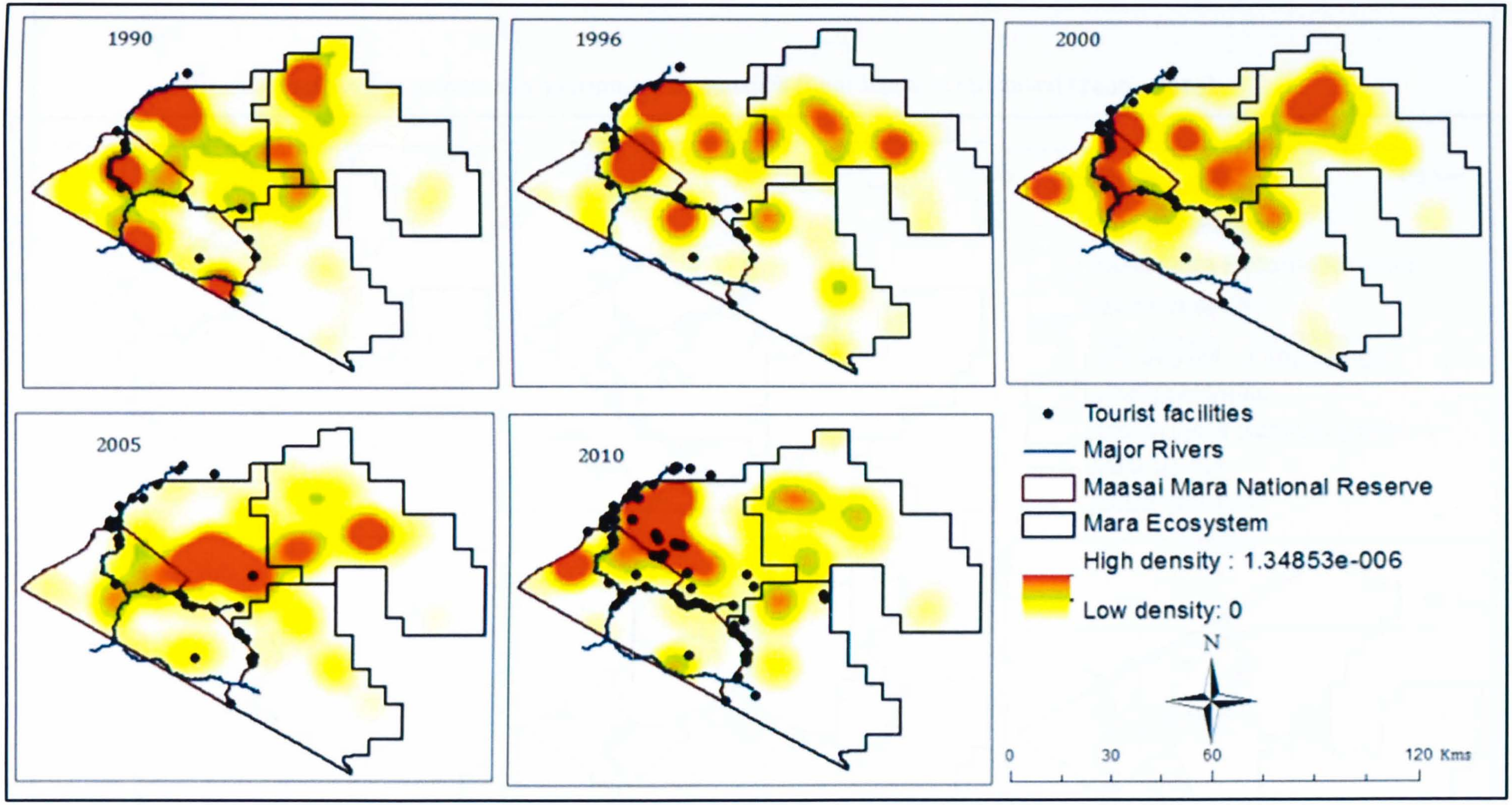

Figure 5.2i Density and distribution of Thompson's Gazelle (*Gazella rufifrons*) (1990 – 2010)

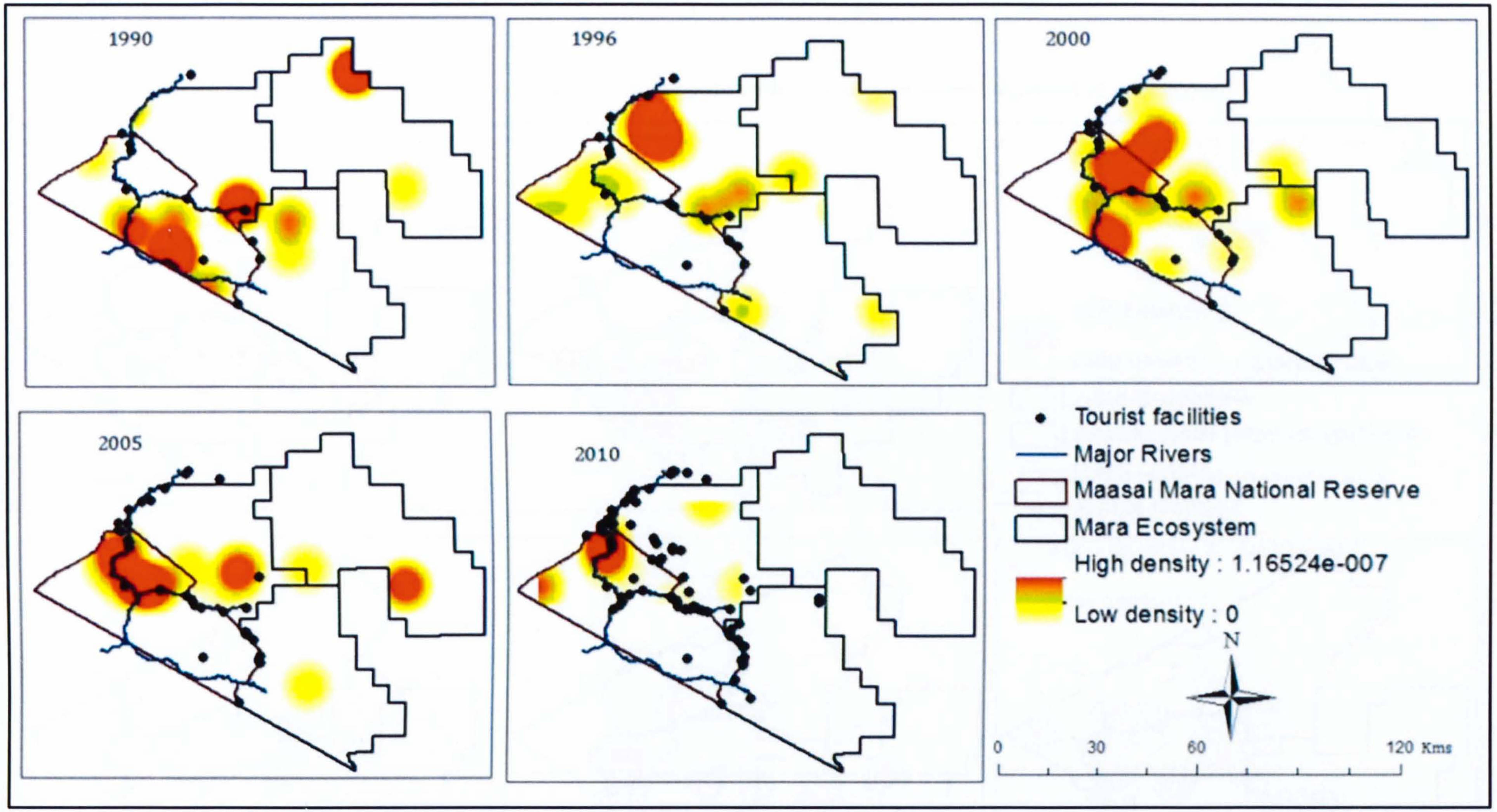

Figure 5.2j Density and distribution of Warthog (*Phacochoerus africanus*) (1990 – 2010)

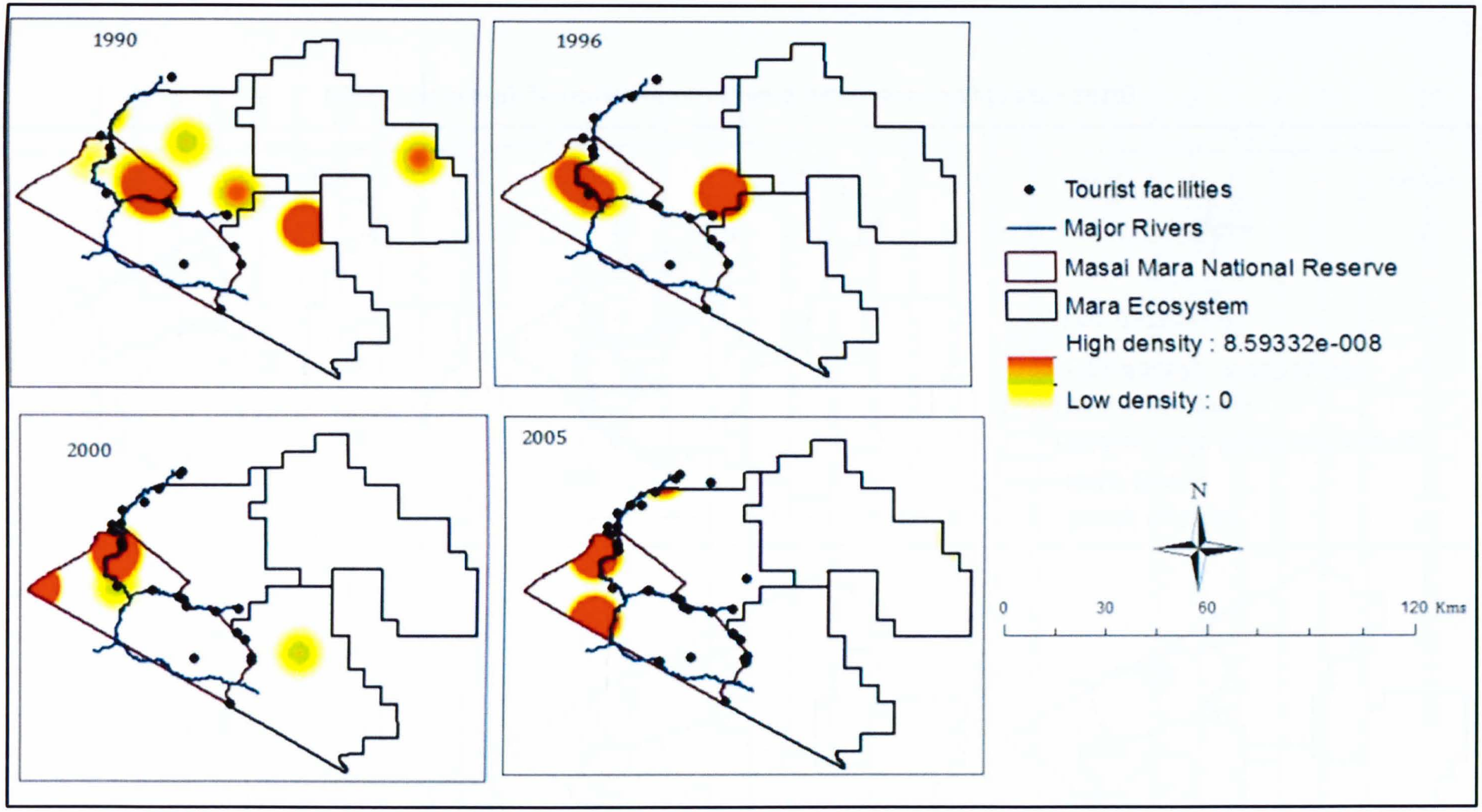

Figure 5.2k Density and distribution of Waterbuck (*Kobus ellipsiprymnus*) (1990 – 2005)

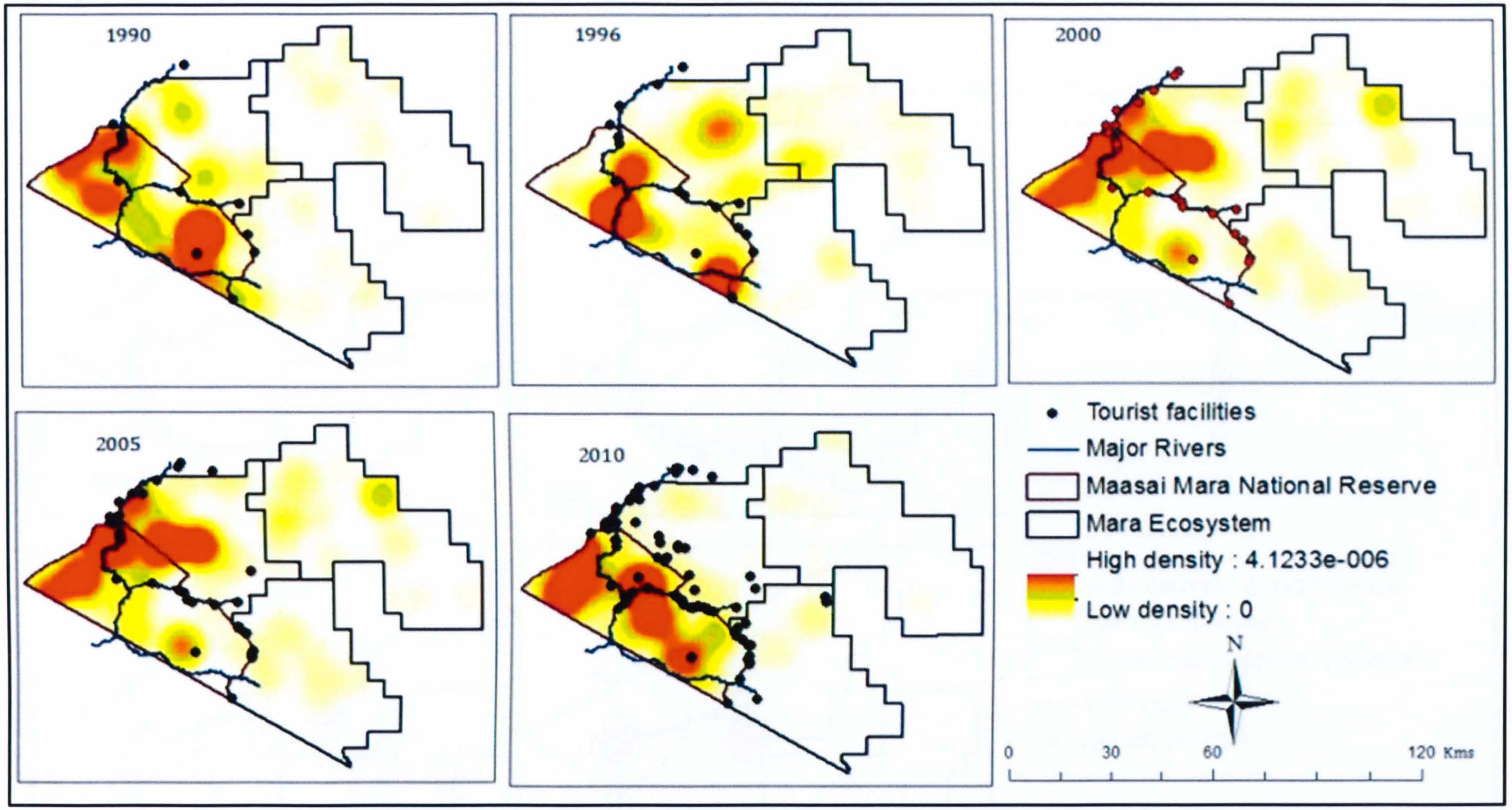

Figure 5.2l Density and distribution of Zebra (*Equus burchelli*) (1990 – 2010)

5.5.3 Changes in area occupied by study species

A major aim of this study was to examine ungulate distribution in the Mara Ecosystem through a twenty year period taking into account tourism induced changes occurring in this landscape and to determine any significant difference in these changes in and out of the protected area. This information is valuable in that the geographic range size of a species and how it changes over time is one of its fundamental and evolutionary characteristics, and a strong predictor of extinction risks (Gaston and Fuller, 2009).

Using the kernel density maps, total area (km^2) occupied by each of the study species in the ecosystem was calculated and compared over the 20 year period taking differences between area covered in the protected area (Maasai Mara National Reserve) and the dispersal areas (Mara ranches) into account. To calculate species area, the GIS spatial analyst tool was used to build and execute a map algebra expression **(Species density map >0)** using python syntax in a calculator-like interface to calculate the number of pixels covered by the density map resulting in binary codes, with 1 indicating occupied pixels and 0 indicating empty pixels . Once the pixel counts were computed, the total area covered by each of the species was calculated using the following expression:

Area (km^2) = z (x,y) where z is number of raster cells with value of 1; x is width of raster cell (0.5km) and y is length of raster cell (0.5km).

To compare differences in areas occupied by species between the reserve and the ranches between 1990 and 2010, bar charts (Fig 5.3a-d) were created with a line graph showing total area occupied in the ecosystem inserted and mean sample t-tests run (Tables 5.2 and 5.3). Elephant and buffalo ranges showed an increase in the National Reserve over the period between 1990 and 2010. However, during critical periods, such as drought, both species which preferentially select habitats near water (Ryan, 2006) ranged further for higher quality food. Elephant and buffalo are particularly vulnerable to land use intensification and have significant direct negative impacts on people, livestock and agriculture (Worden et al., 2003). Buffalo are also disease reservoirs for livestock, while traditional elephant migration routes in the Mara Ecosystem especially in the ranches have been fenced off putting them in direct-conflict with local communities, hence their ranges were mostly restricted to the protected area.

Giraffe, Kongoni, Eland, Warthog, Topi and Waterbuck showed the highest loss in area occupied in the ecosystem in accordance with findings from previous studies by Ogutu *et al.*, (2011), Ogutu *et al.*, (2009) and Ottichilo (2000) which indicated a dramatic reduction in the Mara's ungulate populations. Eland, which cluster away from settlements and livestock (Reid *et al.*, 2003), showed a sharp decrease in range in the ranches from 1996 and a subsequent increase in the protected area. However in 2010, their range in the ranches increased to 450.5km^2 from 399.5km^2 in 2005 as they moved back into the newly created conservancies. Impala, Grant's gazelle, Thompson's gazelle and Zebra were found to consistently occupy most or all of the National Reserve, but showed a gradual decline in the total area occupied in the ranches over the twenty year period. Thompson's gazelle and zebras have improved grazing opportunities in the ranches as they are attracted to the short grass close to human settlements and the nutrient-rich sites of old cattle kraals (Lamprey and Reid, 2004b) consequently increasing their range. Impala also show a wide range in the group ranches due to their low to moderate dietary overlap with livestock and the presence of large areas with woody plants (Reid *et al.*, 2003).

It was noted however that the area occupied by the study species in the National Reserve increased over the twenty years while the amount of land they occupied in the ranches, though still greater, showed a reduction in size, indicating increasing preference for the protected area by the ungulates. This shift is a likely result of the conflicting land uses in the surrounding ranches caused by subdivision and fencing of private land which has created a fragmented landscape and increased competition with livestock and conflicts with the local communities. The creation of wildlife conservancies outside the protected area is perceived as a way to increase areas free of agriculture and overdevelopment, both of human settlements and tourist facilities, for wildlife. This increase in range outside the reserve is already evident in the ecosystem's eland population.

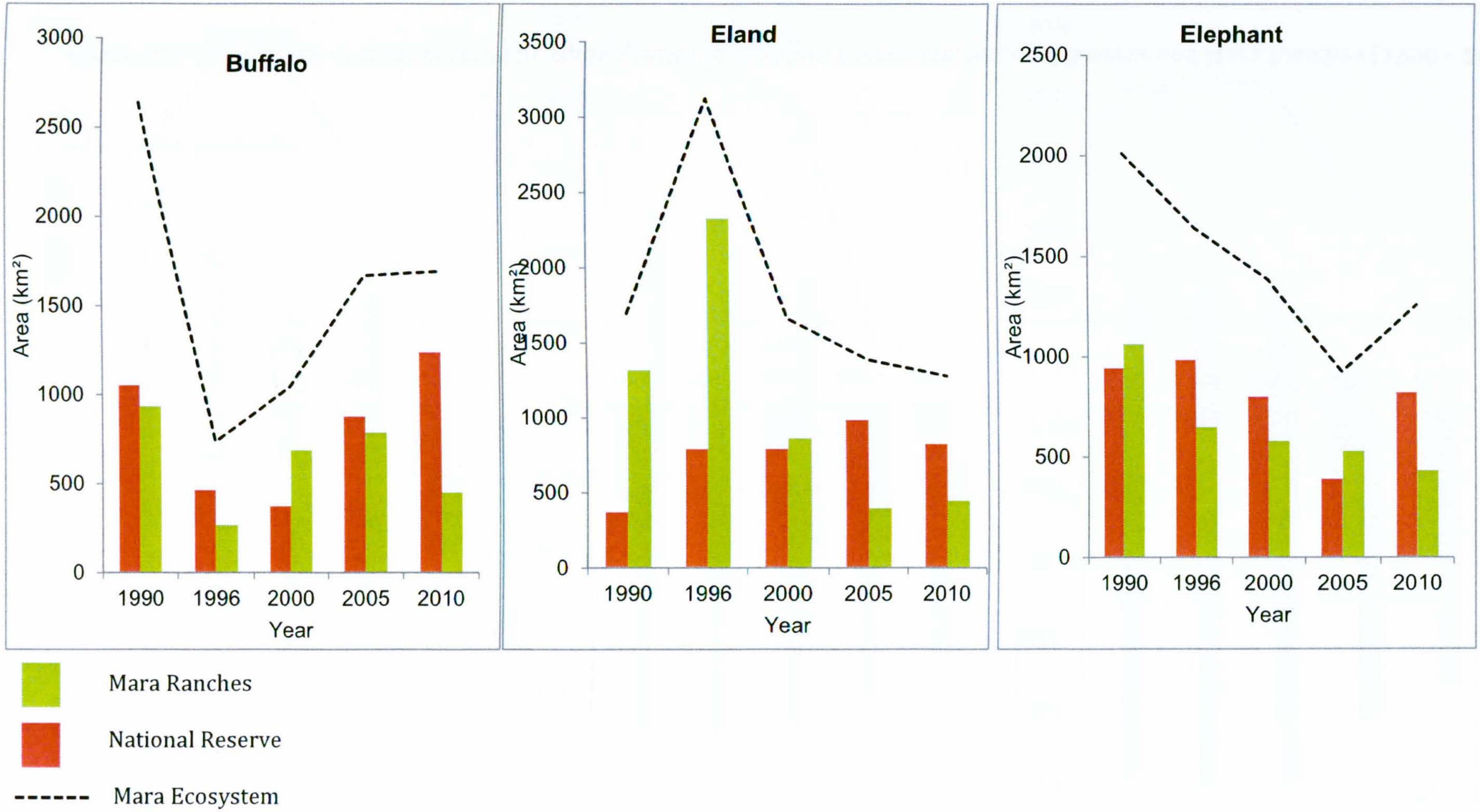

Figure 5.3a Comparison of areas covered by study species in the Mara Ecosystem, National Reserve and Mara Ranches (1990 – 2010)

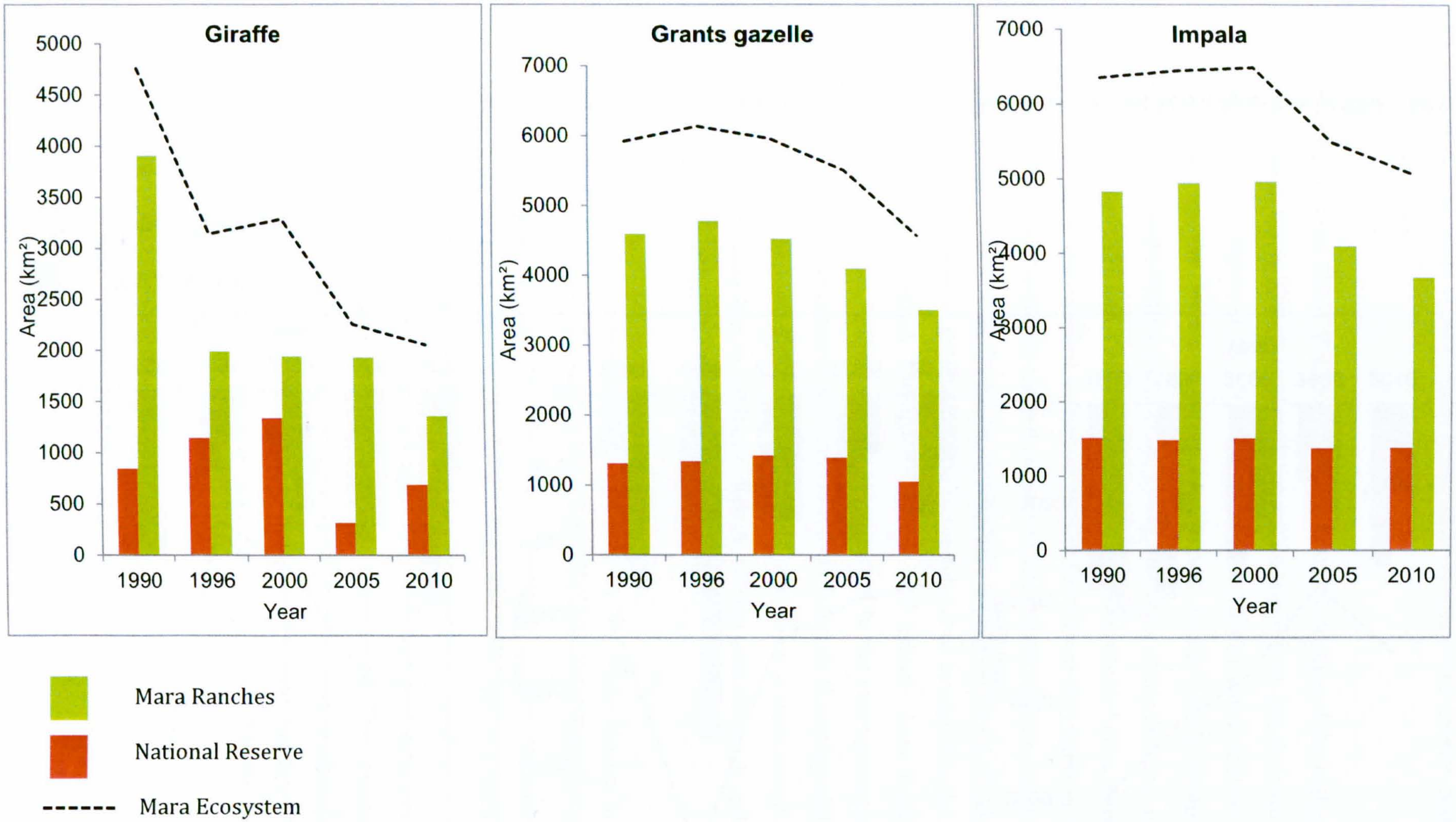

Figure 5.3b Comparison of areas covered by study species in the Mara Ecosystem, National Reserve and Mara Ranches (1990 – 2010)

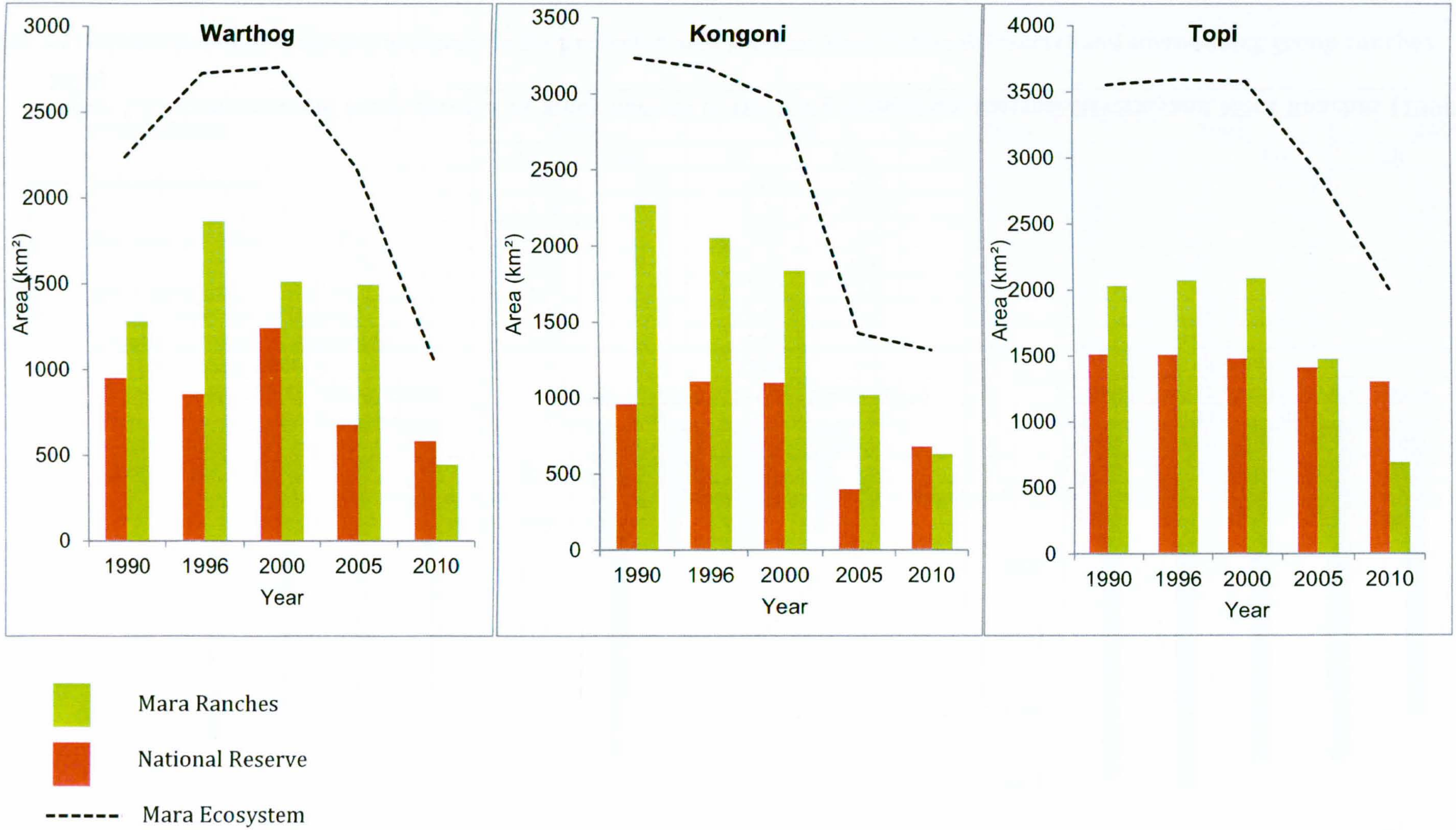

Figure 5.3c Comparison of areas covered by study species in the Mara Ecosystem, National Reserve and Mara Ranches (1990 – 2010)

Figure 5.3d Comparison of areas covered by study species in the Mara Ecosystem, National Reserve and Mara Ranches (1990 – 2010)

Table 5.1: Wildlife population density estimates in the protected area (Maasai Mara National Reserve) and surrounding group ranches

SPECIES NAME	Estimated population density per Km^2									
	1990		1996		2000		2005		2009*	
	NR	MR	NR	MR	NR	MR	NR	MR	NR	MR
Buffalo(*Syncerus caffer*)	5.62	0.27	0.03	0.03	0.85	0.23	5.75	0.04	5.11	0.04
Eland (*Taurotragus oryx*)	0.06	0.10	0.12	0.30	0.13	0.20	0.22	0.08	1.08	0.03
Elephant (*Loxodonta africana*)	0.60	0.11	0.39	0.08	0.03	0.18	0.14	0.25	0.47	0.11
Giraffe (*Giraffa camelopardalis*)	0.24	0.31	0.23	0.18	0.12	0.74	0.18	0.15	0.22	0.16
Grant's Gazelle (*Gazella granti*)	1.31	1.81	1.01	3.01	0.40	6.91	0.61	1.87	1.44	0.64
Impala (*Aepyceros melampus*)	6.15	7.44	3.47	6.32	0.70	17.79	1.29	5.94	2.79	2.18
Kongoni (*Alcelaphus buselaphus*)	0.92	0.19	0.50	0.36	0.11	0.36	0.06	0.12	0.17	0.09
Topi (*Damaliscus lunatus*)	2.64	1.46	3.95	0.64	0.51	1.99	2.64	0.49	2.27	0.44
Thompson's Gazelle (*Gazella rufifrons*)	9.09	4.88	3.75	4.30	2.28	12.31	4.71	6.27	6.51	2.24
Warthog (*Phacochoerus africanus*)	0.18	0.03	0.15	0.20	0.18	0.52	0.31	0.08	0.73	0.20
Waterbuck (*Kobus ellipsiprymnus*)	0.18	0.06	0.12	0.04	0.02	0.00	0.20	0.00	0.31	0.01
Zebra (*Equus burchelli*)	39.04	3.99	37.06	5.64	4.08	10.67	0.58	7.26	26.22	1.20

Notes: NR – Maasai Mara National Reserve, MR -Mara Ranches *Computed 2010 population estimates not available from DRSRS at time of publishing. 2009 estimates have been used as alternative

Mean sample t-tests were run to:

i. Compare significant differences in area (km^2) occupied by the study species in the Maasai Mara National Reserve (protected area) and the Mara ranches (dispersal areas)

ii. Compare total change in area covered by all species in the Maasai Mara National Reserve (protected area) and the Mara ranches (dispersal areas) in the twenty years ranging from 1990 to 2010.

Species by species comparison of National Reserve and Mara ranches

Table 5.2 Paired samples t-test comparing area occupied by species in Maasai Mara National Reserve and the ranches between 1990 and 2010 at 95% confidence levels

Species	df	t-stat	p-value
Buffalo *(Syncerus caffer)*	4	0.997	0.347
Eland *(Taurotragus oryx)*	4	-0.789	0.474
Elephant *(Loxodonta africana)*	4	1.229	0.286
Giraffe *(Giraffa camelopardalis)*	4	-2.932	0.043*
Grant's Gazelle *(Gazella granti)*	4	-16.541	0.000*
Impala *(Aepyceros melampus)*	4	-13.095	0.000*
Kongoni *(Alcelaphus buselaphus)*	4	-3.189	0.033*
Topi *(Damaliscus lunatus)*	4	-0.987	0.380
Thompson's Gazelle *(Gazella rufifrons)*	4	-18.741	0.000*
Warthog *(Phacochoerus africanus)*	4	-2.239	0.088
Waterbuck *(Kobus ellipsiprymnus)*	3	-0.110	0.920
Zebra *(Equus burchelli)*	4	-18.618	0.000*

df =degrees of freedom, *significant difference between ranches and reserves ($p<0.005$)

There was a significant difference in amount of space occupied in the two areas by Giraffe ($t(4)= -2.932$, $p=0.043$); Grant's gazelle ($t(4)= -16.541$, $p= 0.000$); Impala ($t(4)= -13.095$, $p=0.000$); Kongoni ($t(4)= -3.189$, $p= 0.033$); Thompson's gazelle ($t(4)= -18.741$, $p=0.000$) and Zebra ($t(4)= -18.618$, $p= 0.000$) which occupied larger areas in the ranches.

Year by year comparison of area occupied by study species in the National Reserve and Mara Ranches

Table 5.3 Paired samples t-test comparing changes in species coverage in the protected area (Maasai Mara National Reserve) and dispersal areas (Mara Ranches) at 95% confidence levels.

Year	df	t value	p-value
1990	11	-4.317	0.001*
1996	11	-30361	0.006
2000	11	-2.932	0.014*
2005	11	-2.841	0.016*
2010	11	-1.724	0.113

df= degrees of freedom, *significant difference in area covered by all species between Maasai Mara National Reserve and Mara ranches ($p<0.005$)

There was a significant difference in area occupied by the study species between the protected area and the ranches in 1990 ($t(11)= -4.317$, $p= 0.001$); 2000 ($t(11)= -2.932$, $p= 0.014$) and 2005 ($t(11)= -2.841$, $p= 0.016$). In 1990, the ranches were communally owned and registered as trust lands with large areas unoccupied as the local Maasai freely moved all over the ecosystem with their cattle and as such, there were few permanent settlements. Furthermore, there were only 11 tourist facilities in the Mara with the majority in the protected area. These factors all contributed to fewer incidences of human-wildlife conflict with more space available in the dispersal area for wildlife. The changes in location and amount of area occupied in 2000 and 2005 may have resulted from the previous years' droughts causing the animals to disperse into the ranches for pasture and to reduce their susceptibility to predation.

5.6 Discussion

This component of the research highlighted changes in ungulate densities in the Mara Ecosystem with some of the study species hotspots being spatially shown to change as a consequence of tourist facility presence. This study recognizes that tourist developments are not the only factor leading to changes in species hotspots, with previous studies highlighting the impacts of agricultural expansion in wildlife dynamics. However, tourism as an alternative land use and source of livelihood has the potential to further contribute to the loss of wildlife habitat if it is not appropriately regulated. The development of tourist facilities in the Mara Ecosystem has been rapid in response to the increasing number of tourists. This has led to habitat destruction and consequently a reduction in wildlife numbers and a loss in their range, particularly their wet season grazing and dispersal areas, as demonstrated by the species density and distribution maps. It has been noted that in an attempt to provide wildlife viewing opportunities from lodges, tourist facilities have mushroomed in ecologically fragile areas of the ecosystem that serve as breeding and calving grounds for many wildlife species and increased habitat fragmentation in these areas (Mundia and Murayama, 2009) resulting in decreased wildlife numbers and increased incidences of human-wildlife conflict.

The continued loss of available wildlife habitat to both small scale subsistence and mechanized agriculture and the fragmentation of trust land through privatisation in the Mara Ecosystem is expected to cause more decline in the wildlife population, through increased resource competition between wildlife, livestock and local communities (Said, 2003). A similar study to Said's (2003) in the Amboseli Ecosystem investigating the impact of subdivision and land use change on wildlife migration found that the growing human population and their increasing subsistence demands on educational and health infrastructure, combined with land subdivision in several group ranches, had interfered with wildlife migration routes and reduced the size of important wildlife dispersal areas, negatively affecting the protected area (Wayumba and Mwenda, 2006). A recent study by Craigie *et al.*(2010) noted that most protected areas in Africa have generally failed to mitigate human-induced threats to large mammal populations with a general decline in wildlife populations noted in most East and West African protected areas. Only Southern African protected areas, managed specifically for their large mammals and primarily for tourism, showed increasing wildlife populations. The same authors note that their intensive management strategies, such as waterhole provision and translocation can lead to unexpected adverse impacts on biodiversity such as the decline of the roan antelope (*Hippotragus equinus*) in Kruger National Park. In order to maintain or assist wildlife populations' ability to recover, mitigation of human-induced impacts in the Mara Ecosystem is therefore of the utmost importance.

Total area counts, where all the animals in a census zone are located and counted, are considered best for wildlife studies, but sample counts are more commonly undertaken as they are time and cost efficient (Marriott and Wint, 1985). Sample counts have however been noted as biased in that they may under count large wildlife groups, fail to observe small groups, fail to count animals which may be undercover or obscured by other animals. Marriot & Wint (1985) and Norton-Griffiths (1978) explain that observer training can greatly reduce errors and that photographs of large herds can be used to get accurate counts. They further add that if the main purpose of a survey is to estimate change and successive surveys are conducted in exactly the same way, the biases tend to cancel out. This study has therefore used post-1990 count data which used a consistent field methodology.

The use of kernel density estimation for hotspot identification while more accurate than point density, was not able to create density surfaces for single point observations as evidenced by the 2010 waterbuck data, and may affect comparison of changes in distribution and range size. However, the use of kernel density estimation maps for the identification of wildlife hotspots enables land use planners and wildlife managers to spatially visualise areas with high wildlife densities and identify conservation areas with high potential ecological value ('warm' spots). There are however some limitations to the use of kernel density estimations such as the appropriate search radius, resolution and the optimal kernel threshold to apply. While this study utilised the upper range of the index to identify species hotspots, further work is needed to explore the optimal threshold range appropriate for identifying an absolute hotspot size as the size and shape of a hotspot changes depending on the range used (Alessa et al., 2007).

The calculation of total area occupied by the study ungulate species and the comparison between protected and dispersal areas, indicated that despite the changes in the Mara's landscape, wildlife continue to utilise their historical dispersal areas in the surrounding ranches spending the majority of their time in these 'unprotected' areas, thus highlighting the importance of conservation being extended to these dispersal areas. Since 2006, several conservancies, comprising voluntary partnerships between private tourism investors and land owners in the Mara ranches, have been created to act as complimentary conservation areas to the Maasai Mara National Reserve. These agreements require land owners to voluntarily vacate their land for wildlife in exchange for regular monthly land rents. Wildlife conservancies have therefore been perceived as a novel way to promote the recovery of wildlife populations in non-protected areas (Accada and Neil, 2006, Ogutu *et al.*, 2009) thus reducing pressure in protected areas which are unable to independently sustain viable wildlife populations, minimize incidents of human wildlife conflict and absorb the growth of tourist developments. With the increase in the number of conservancies in this ecosystem, it is expected that in future, wildlife populations will gradually increase in these areas which are located away from the Maasai Mara National Reserve, taking pressure caused by tourism away from it. This increase has already been observed in the eland population for example (Figures 5.2b) which has expanded its range into the new conservancies. Further research is therefore needed to study the impacts these conservancies have on ungulate and other wildlife populations and their distribution patterns as well as investigating changes in habitat quality after the exclusion of livestock from these areas. It should be noted that although livestock directly competes with wildlife species such as zebra and gazelles for forage in the dry season; their integration has been discouraged by conservationists. Grazing preference by wildlife to taller grasses in the wet season benefits cattle by improving forage quality which in turn highlights the ecological processes that promote coexistence among large herbivores in grasslands (du Toit, 2011). This should be explored further as a potential way of incorporating traditional Maasai lifestyle with wildlife conservation.

Said (2003) notes that most of the current wildlife policies in East Africa are based on historical wildlife distribution and status and have not taken into account impacts that increasing intensive agriculture and livestock husbandry over the last half of the century have had on wildlife in places such as the Mara Ecosystem. These land use changes and the resulting reduction in available wildlife range as demonstrated by this research, the increasing cases of human-wildlife conflict, a direct result of increased human population and change in land tenure, all challenge the popular perception that wildlife and people can peacefully coexist. Kenya's National Tourism Policy (Ministry of Tourism and Wildlife, 2006) was developed to address these issues and seeks to harmonise the existing national policies on land-use, wildlife and tourism to ensure consistency between tourism development and wildlife conservation, and to minimise human-wildlife conflict. The implementation of this policy is essential to resolve these concerns which are especially prevalent in dispersal areas, without which conservation areas in Kenya cannot effectively and sustainably support viable wildlife populations, and the tourism industry that relies on it (Okech, 2010). The creation of conservancies and alternative wildlife areas is a first step in reducing wildlife loss and improving their habitats in these dispersal areas, and research into their impacts on biodiversity as well as local livelihoods need to be explored.

Chapter 6

SUITABILITY MODELLING: IDENTIFYING OPTIMAL LOCATIONS FOR PROPOSED ECO-DEVELOPMENTS IN WILDLIFE AREAS

6.1 Introduction

Remote sensing and GIS have the potential to provide useful information for wildlife management through the use of predictive models (Obade, 2008). It provides for visual assessment of wildlife movement patterns, their utilisation of habitats and their interactions with the surrounding environment, making it a powerful tool for conflict mitigation and land-use planning. The last two decades have witnessed a growing interest in species distribution modelling of plants and animals, with recent advances allowing for forecasting anthropogenic effects on biodiversity patterns at different spatial scales (Guisan and Thuiller, 2005). Segurado and Araujo (2004) explain that these models, which explore the relationship between species occurrence and a set of environmental variables, produce two kinds of results; estimates of the probability that species might occur at given unrecorded locations and an area's suitability for an individual species. For example, in Kenya, the use of comprehensive predictive mapping derived from spatial models and the use of empirical data from dung pile counts, has been successfully used to identify areas of high elephant density and the habitats they move between on Mt. Kenya (Vanleeuwe, 2010). Similarly, this research (Chapter 5) used GIS mapping to identify distribution trends of twelve ungulate species over a twenty year period, to understand their response to increased tourism development in the Mara Ecosystem.

By providing data management frameworks which can be used to integrate, manipulate and visualize a wide diversity of spatial and non-spatial data sets, GIS has the capability to address planning issues such as land-use suitability analysis (Feick and Brent-Hall, 2000) and can assist users to answer questions concerned with geographical patterns and processes (Malczewski, 2004). Land use suitability analysis in a GIS identifies the most appropriate spatial patterns for future land uses of given activities according to specified requirements, preferences or predictors (Malczewski, 2004). It is commonly used to select locations for species reintroductions by identifying areas of suitable habitats and species-specific environmental variables, such as elevation and temperature. Site selection analysis, which is similar to land use suitability analysis, examines and creates an understanding of an existing site's qualities and factors which can then be used to determine suitable alternative locations for a particular activity (Kamal and Subbiah, 2007) and has been used to identify suitable locations for housing developments, schools and landfill sites.

Both land use suitability and site selection analyses make use of GIS-based multi-criteria decision analysis (MCDA), a decision support technique that transforms and combines geographical data (map criteria) and decision-makers' preferences to obtain appropriate and useful information for decision-making. MCDA provides a collection of procedures and algorithms for designing, evaluating and prioritizing alternative decisions (Boroushaki and Malczewski, 2010, Arafat *et al.*, 2010) and is viewed as a data conversion process that adds extra value to the original data (Drobne and Anka, 2009). If well applied, MCDA can be successfully used by wildlife managers and policy makers to determine the suitability of proposed tourist developments in popular wildlife areas such as the Mara, as well as developing underutilised or new wildlife areas by selecting suitable locations for new lodges in these areas.

This research has demonstrated (in Chapters 4 and 5) that, excluding all other external factors such as spread of both small-scale and mechanized agriculture, increased human population and climate change, the current unsustainable levels of tourism in the Mara Ecosystem is a major component in the reduced number of wildlife species, leading to urgent calls for its regulation. The rapid growth of tourist facilities, especially in the Talek, Sekenani and Oloolaimuita areas, has impacted heavily on wildlife in those areas, as shown in the 20 year species density and distribution maps in Chapter 5. One of the main objectives of this study was therefore to use GIS analysis methods, including those provided by MCDA, to integrate features influencing wildlife distribution patterns into models to determine the suitability of specific locations for proposed tourist developments in the Mara Ecosystem, in an attempt to halt the current negative impacts imposed on by the receiving environment and its wildlife populations.

6.2 Research questions

i. How can GIS modelling be used to identify optimal locations for any new tourist developments in wildlife areas?
ii. Which are the most suitable modelling strategies that can be employed by decision makers to indicate levels of acceptability of any proposed developments?
iii. How best can these strategies be used to inform and influence policy direction in relation to tourism planning in wildlife areas?
iv. Which model best combines available parameters to identity a suitable location for proposed tourist developments?

6.3 Methodology

The combined use of GIS and MCDA provide a powerful approach to suitability assessments and creation of suitability models where the GIS is used to compute the selected criteria and the MCDA groups them into a suitability index capability (Florent et al., 2001). To run suitability models, appropriate base data were acquired from current and historical datasets, evaluated and the relevant layers identified (Table 6.1) and extracted using spatial analyst tools in ArcGIS which contains tools and functions that are able to derive new information from overlaid multiple layers and provide a comprehensive modelling environment for spatial analysis (ESRI, 2001).

Table 6.1 Variables used in site suitability models

Variables	Description	Source
Mara Ecosystem and Maasai Mara National Reserve	MMNR is the protected section of the study area and is jointly managed by the Narok and Trans Mara County Councils. Distance to reserve border is continuous, ranging from 0 to 20km.	KWS, DRSRS
Wildlife hotspots	Density maps developed according to feeding guilds. Continuous variables from 1 (low density) to 9 (high density)	DRSRS
Distance to roads	Distance to major road network in the ecosystem. Continuous, ranging from 0 to 4km.	KWS
Distance to water	Distance to major rivers and streams. Continuous, ranging from 0 to 2km	KWS
Land use cover	Includes land cover in the ecosystem. Categorical: agricultural, bush land, forest, woodland and grassland.	DRSRS
Distance to tourist facilities	Distance to tourist facilities. Continuous, ranging from 0 to 10km.	KWS, Self
Distance to settlements	Distance to permanent human settlements. Continuous, ranging from 0 to 10km.	KWS
Distance to airstrips	Distance to airstrips. Continuous, ranging from 0 to 10km	KWS

KWS – Kenya Wildlife Service; DRSRS – Department of Resource Surveys and Remote Sensing

Once relevant layers for the selected parameters had been identified, a GIS was used to convert them to rasters (matrix of cells or pixels organised into grids where each cell contains a value representing information for the area covered by that cell (ESRI, 2011)). The rasters were then reclassified using a suitability index and weighted, as shown in Figure 6.1 and described below, to develop site suitability models under different scenarios.

i. **Selection of significant parameters:** Once the relevant datasets were in place, several tools were applied to them to generate modelling conditions. For each of the selected variables, multiple ring buffer analysis was used to create buffers at specified distances and the straight line distance function used to calculate the Euclidian distances from the centre of the selected variables to surrounding cells. These buffer maps were then converted into raster layers of uniform grid sizes and reclassified in readiness for modelling.

ii. **Reclassification:** To create a suitability model, each of the selected layers was classified to a common scale by reclassification of data units. The relative suitability of each of the selected / created layers was determined using a linear scale of nine suitability values where the cell of each input raster in the analysis was assigned a suitability value. These are:

1 = lowest suitability
2 = very low suitability
3 = low suitability
4 = moderately low suitability
5 = moderate suitability
6 = moderately high suitability
7 = high suitability
8 = very high suitability
9 = highest suitability

iii. **Weighting of layers:** Each of the thematic maps were converted into raster form, where each pixel was assigned a score. To assess the overall suitability of a site, each parameter was assigned a percentage influence based on its ranking in the model using the weighted overlay tool. The total influence for all the inputs was therefore equal to 100%. These maps were then combined into a composite suitability map. To weight the layers, the following command was used:

$$([P_1]*a/100) + ([P_2]*b/100) + ([P_3]*c/100) + ([P_4]*d/100) + ([P_5]*e/100)$$

where P_1........P_5 are the selected parameters and a/100.......e/100 are total influence for each parameter where a+b.....+e = 100%

For each of the models, weighting and variable rankings were based on informed discussions with various stakeholders reflecting tourism development priorities.

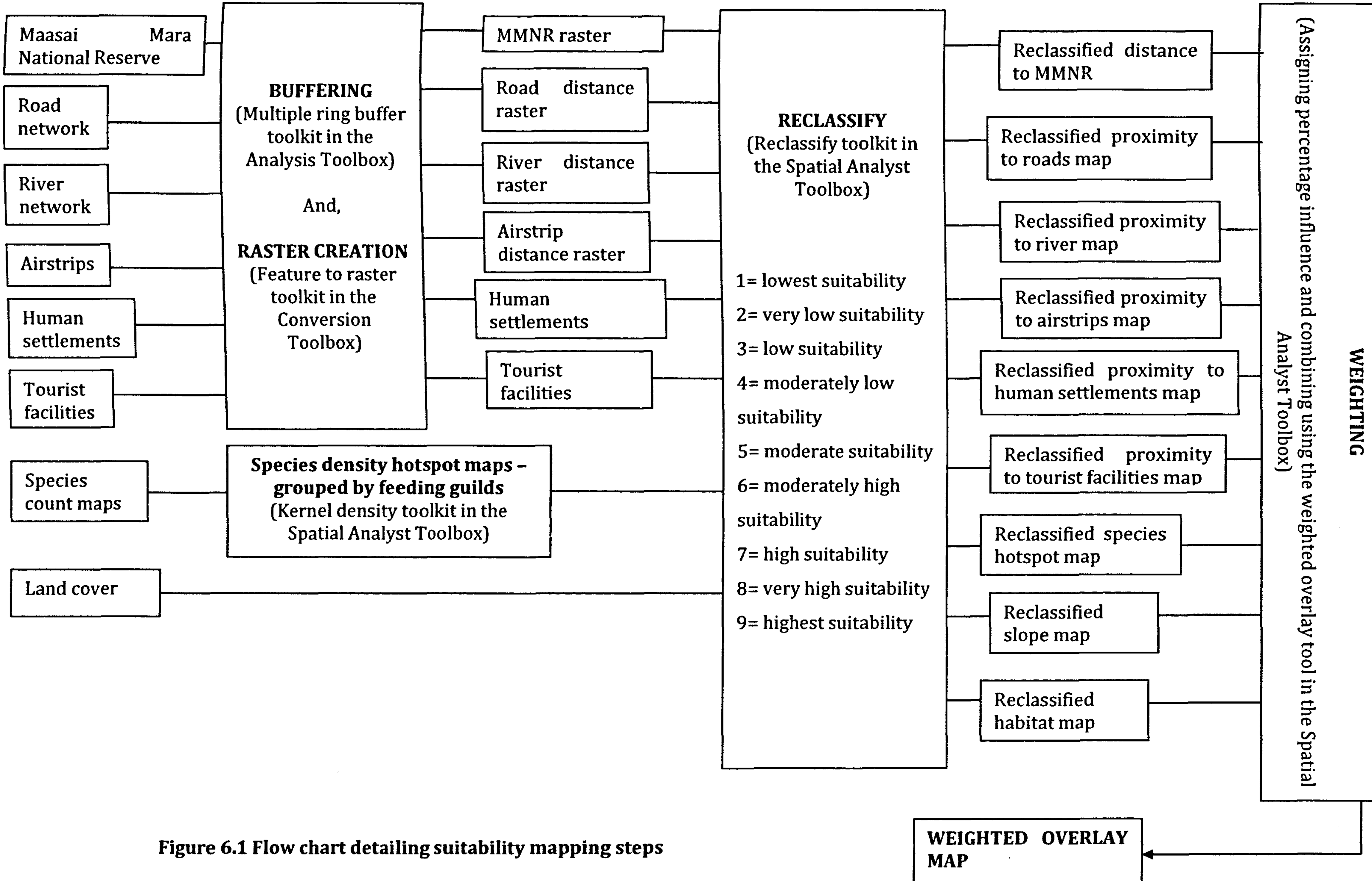

Figure 6.1 Flow chart detailing suitability mapping steps

6.3.1 Site selection parameters

Accessibility to water resources

Water is an important resource for the existence of tourist developments. The growing numbers of tourist facilities are placing greater demand on the river system of the Mara Ecosystem. The existing river system was mapped by KWS and made available for this study. Buffer zones were created taking different distances from the rivers to generate water resource accessibility maps indicating different distance bands as shown in Figure 6.2 which were then reclassified in Table 6.2.

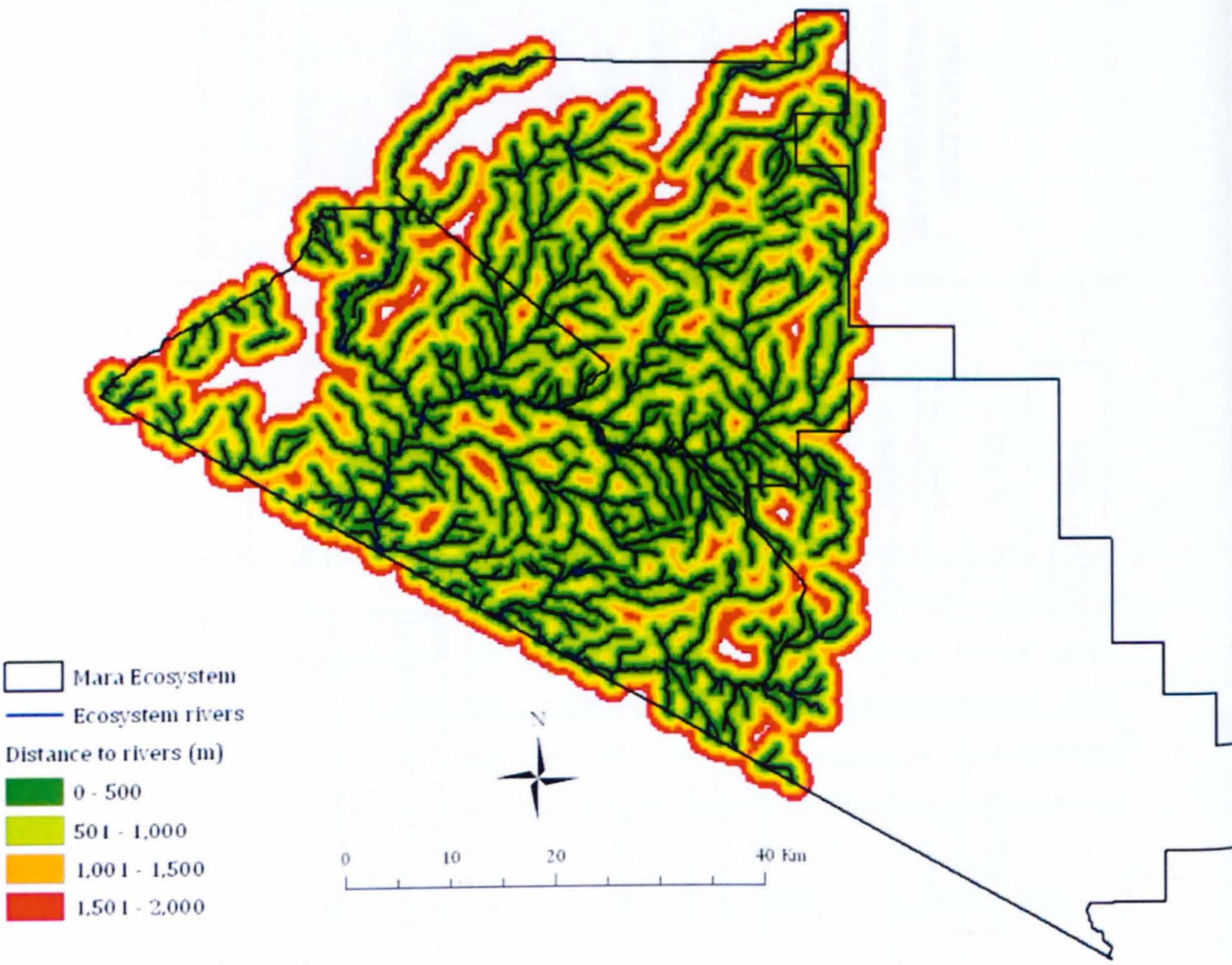

Figure 6.2 Distance to water bodies

Table 6.2 **Suitability scores for distance from rivers**

Distance to rivers (m)	Suitability score	Rationale
0-500	1	Being sited too close to rivers may cause disruption to wildlife. There is also potential for pollution
501 - 1000	4	
1001 - 1500	7	It is predicted that there will be less negative impact in terms of disruption at these distances, while still providing a source of water for use within the facility
1501 - 2000	9	

Accessibility to road network

The presence of and proximity to existing infrastructure is an important criteria when selecting the location of a new facility. Proposed sites must be close enough to ecosystem's existing main road network to allow for access to staff, construction and service vehicles. Reliance on existing road networks reduces the need for new road construction which requires clearing vegetation and is also resource consuming. To assess accessibility of the study area, distance bands were created around the major road network to generate a road accessibility map (Fig 6.3) and reclassification done according for distance from roads (Table 6.3).

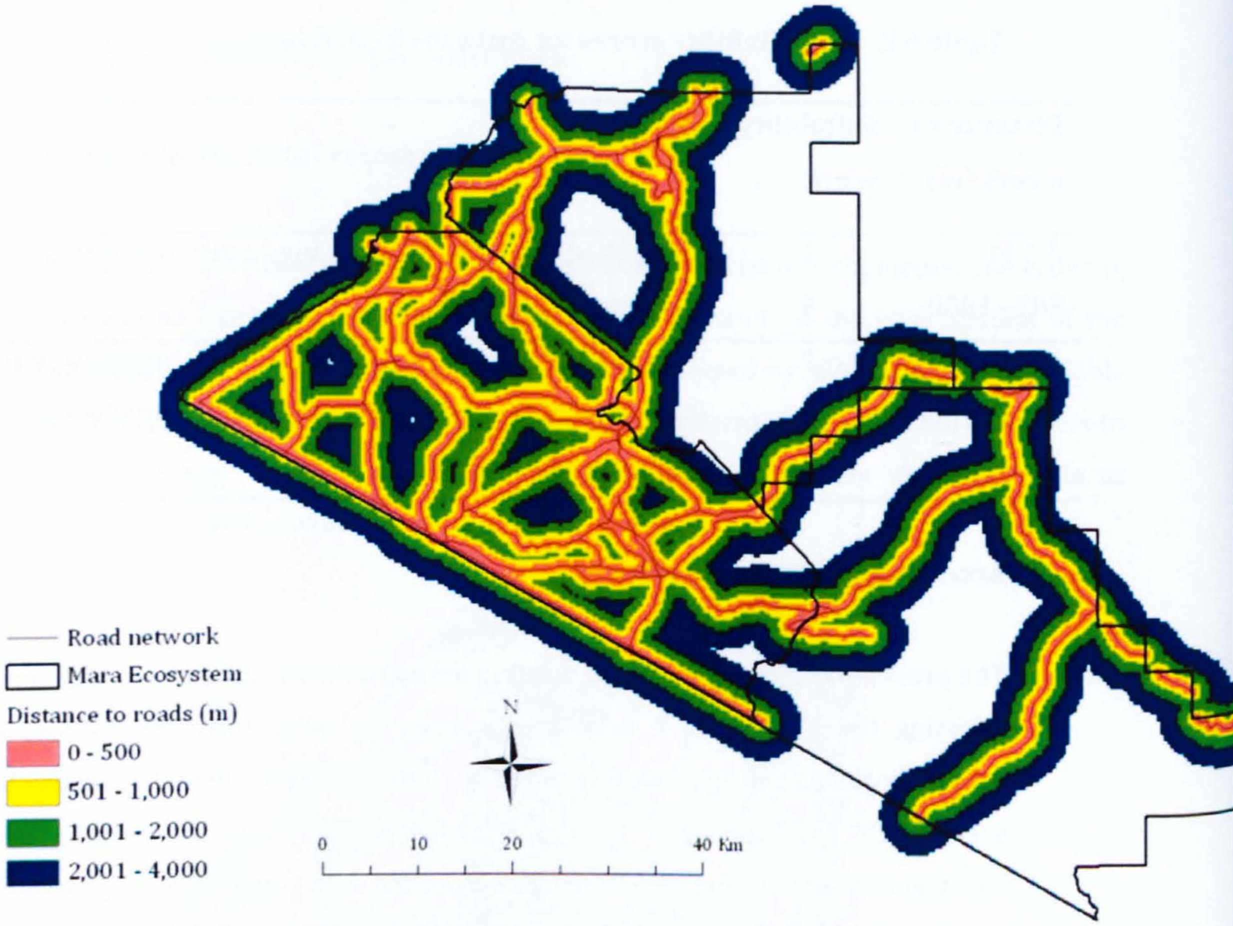

Figure 6.3 Distance to major road networks

Table 6.3 Suitability scores for distance from roads

Distance to roads (m)	Suitability score	Rationale
0-500	9	Sites located close to existing roads will be more accessible
501 - 1000	7	
1001 - 2000	4	Sites located further from road network will require creation of new roads which will lead to loss of vegetation and create disturbance to local wildlife
2001 - 4000	1	

Distance to existing tourist facilities

The Mara Ecosystem has close to 200 existing tourist facilities, and with the increasing popularity of wildlife tourism, there is demand for more facilities. Overcrowding of facilities especially near rivers has put strain on these rivers through pollution and water harvesting and lowered the tourist experience especially for those visitors expecting to visit pristine areas. To limit overcrowding of facilities in particular areas of the ecosystem, future facilities need to be located in the currently under developed areas of the ecosystem. By not having the facilities too close together, visitor experience will be improved and wildlife disturbance reduced. Therefore distance bands were created around existing lodges using multiple buffers (Figure 6.4) to give an indication of proximity of facilities to one another and used to produce a map of suitable areas for new developments (Table 6.4).

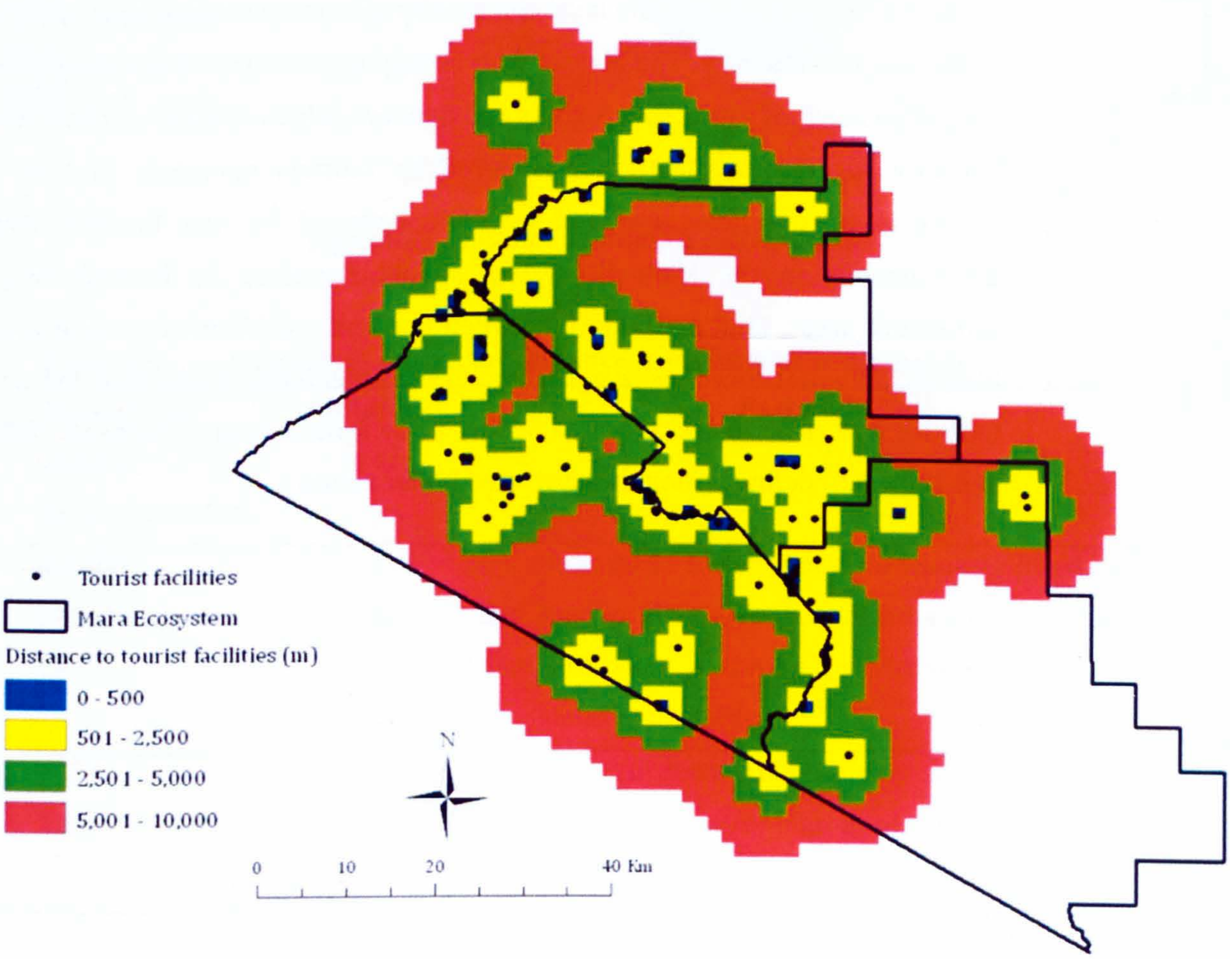

Figure 6.4 Distance to tourist facilities in the study area

Table 6.4 **Suitability scores for distance from existing tourist facilities**

Tourist facility distance (m)	Suitability score	Rationale
0-500	1	Sites close to other lodges limit visitor experience as a result of noise and disturbance from neighbouring facilities
501 - 2500	4	
2501 - 5000	7	Greater distance between lodges is preferred as the tourist experience is enhanced by the perceived seclusion and reduction of disturbance levels from other facilities.
5001 - 10000	9	

Distance to human settlements

The rising human population and subsequent land subdivision to private leaseholders has resulted in increased permanent settlements with small townships emerging close to the National Reserve as the local community gain more employment opportunities in the tourism industry. The Maasai who occupy this ecosystem are pastoralists and own large herds of cattle, sheep, goats and donkeys, which apart from competing with livestock for resources, are not favoured by tourism operators as they appear unnatural in the landscape and are not favoured by the tourists. Any new developments in the Mara Ecosystem should therefore be located away from settlement areas. Multiple buffers between one and ten kilometres were created to identify potential locations away from these settlements. Preference for proposed facilities was given to areas located further away from human settlements (Figure 6.5 and Table 6.5) defined using the generated buffer zones.

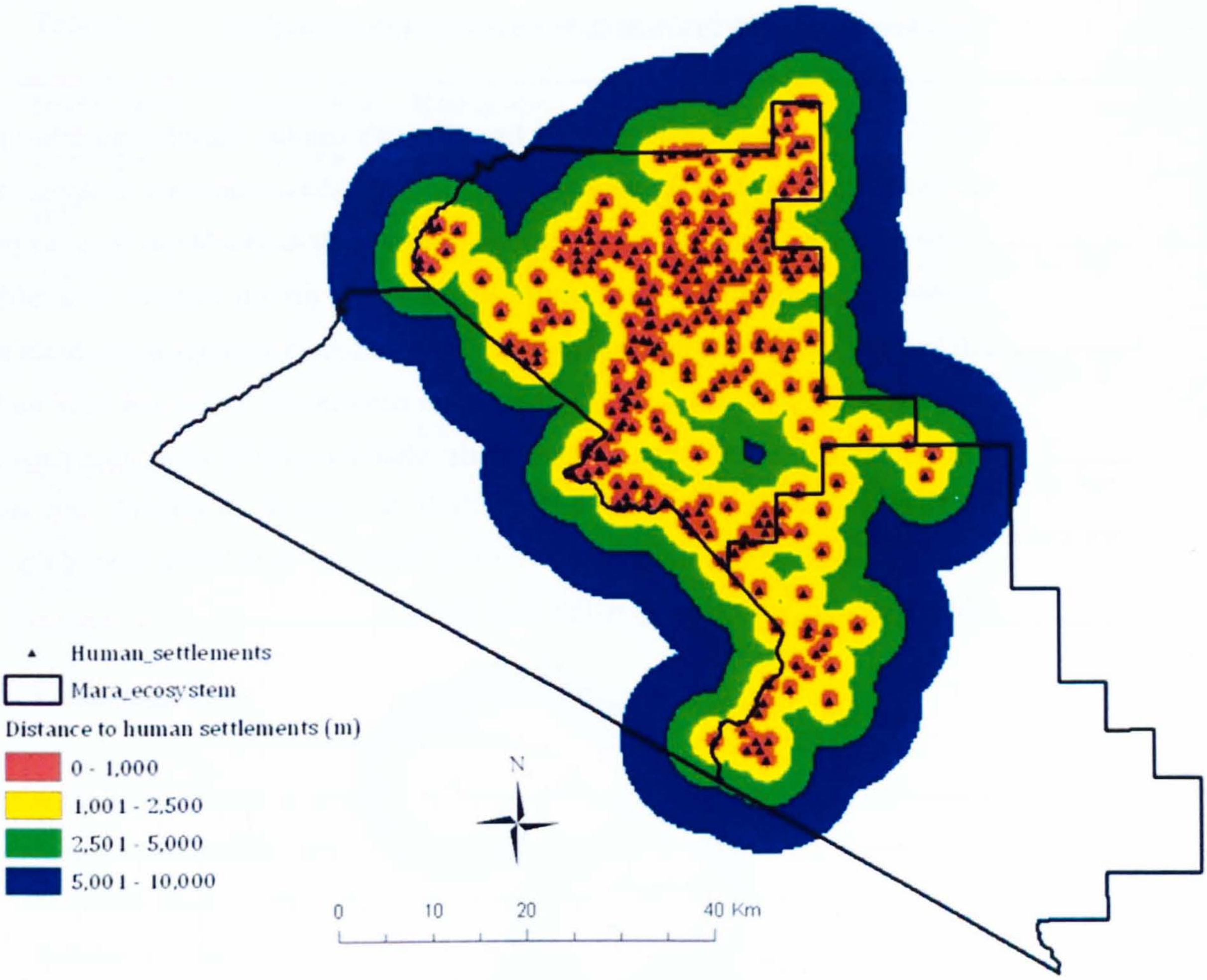

Figure6.5 Distance to human settlements

Table 6.5 Suitability scores for distance from human settlements

Distance to human settlements (m)	Suitability score	Rationale
0-1000 500 - 2500	1 4	Locations close to settlements encounter livestock and human activity cause disturbance to visitors who are after a tranquil environment and are considered unsuitable.
2501 - 5000 5001 - 10000	7 9	Locations furthest from human settlements are preferred as they offer high levels of guest comfort and better wildlife viewing opportunities.

Distance to existing tourism infrastructure (airstrips)

The Mara is easily accessible by air from Kenya's capital, Nairobi and other popular tourist hotspots around the country (Amboseli, Mombasa, Lamu and Laikipia) and due to the poor road network, many tourists choose to fly to the Mara. Sites for potential developments should therefore preferably be within driving distance of airstrips (Fig 6.6 and Table 6.6). It should however be noted that most airstrips in the Mara are only used twice a day to pick and drop tourists on commercial flights, but have no landing restrictions for chartered or private flights. Bhandari (1999) notes that each airstrip requires at least 0.025km^2 of land available for aircraft to take-off and land. The resulting noise is often more 100dB affecting distances up to 500m around the runway which may affect any wildlife within that distance.

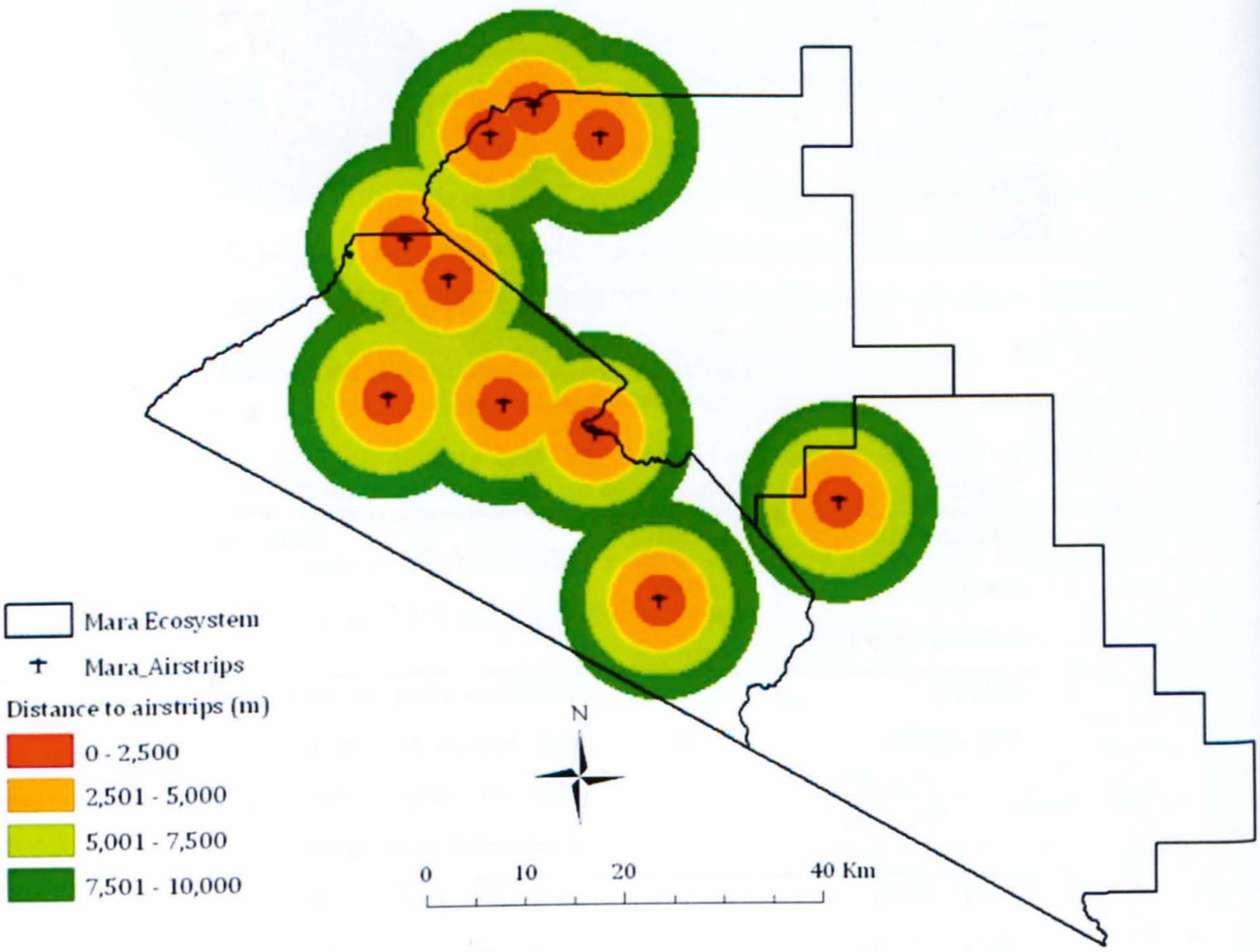

Figure 6.6 Distance to airstrips

Table 6.6 Suitability scores for distance from airstrips

Distance to airstrips (m)	Suitability score	Rationale
0-2500	7	Shorter travel time but noise of aircraft may be too disruptive to wildlife
2501 - 5000	9	Short travel time from airstrips and noise disruption is minimal
5001 - 7500	4	Longer travel time to tourist facility from airstrip but provides a chance to have a game drive and reduces the amount disturbance to wildlife
7501 - 10000	1	

Land cover

A land cover map of Kenya was obtained from the International Livestock Research Institute, ILRI (ILRI, 2011) and using a GIS, clipped to the Mara Ecosystem boundaries to create a land cover map of the study area. The "feature to raster tool" was used to convert the land cover polygons to raster data using the GRID_CODE field in the attributes table (Fig 6.7). This map was then used to identify the most suitable areas for future developments taking into account accessibility and current use e.g. agriculture (Table 6.7).

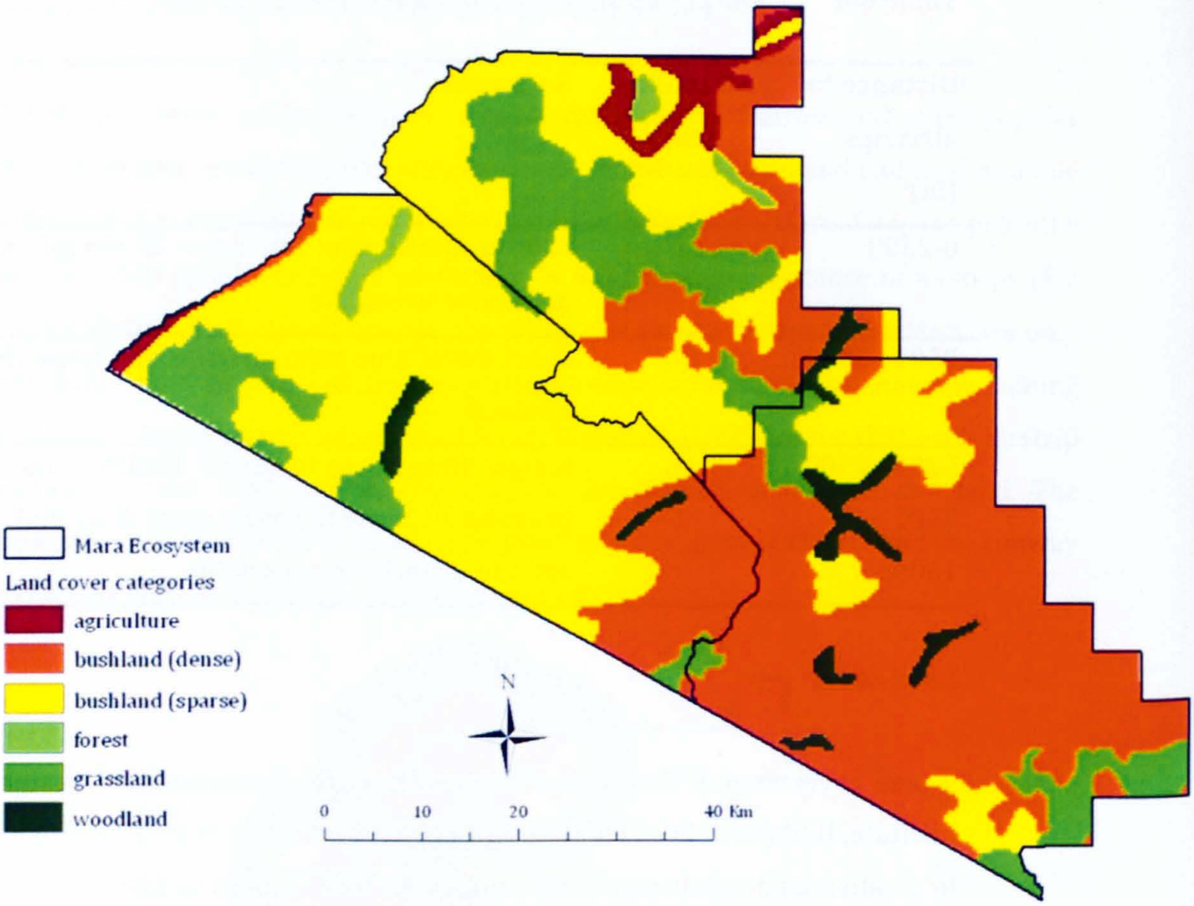

Figure 6.7 Land cover categories in the study area (ILRI, 2011)

Table 6.7 Suitability scores for land use categories

Land cover category	Suitability score	Rationale
Agriculture	1	Not suitable for wildlife, natural habitat has been destroyed and this area is intensively farmed
Dense bush land	2	Good for wildlife viewing but inaccessible and is preferred habitat for keystone species like rhino which are endangered species
Forest	4	
Woodland	5	Preferred as a means of offering shade, but not easily accessible
Sparse bush land	8	Most suitable area for development; accessible with good wildlife viewing opportunities
Savannah grassland	9	

Distance to wildlife hotspots

Wildlife population data obtained from the 2010 DRSRS aerial census was used to identify species hotspots in the study area using spatial analyst tools to create species kernel density maps. These species maps were then combined according to dietary guild (Chapter 4) using map algebra and hotspot areas generated (Figure 6.6) to find locations in the ecosystem offering greater viewing potential for particular species. Density maps were generated for:

a. **All species** = Browsers + Grazers + Mixed feeders
b. **Browsers** = Giraffe + Eland
c. **Grazers** = Buffalo + Topi + Kongoni + Thompsons gazelle + Warthog + Zebra
d. **Mixed feeders** = Elephant + Grants gazelle + Impala

The suitability index was used to score the generated species hotspots with preference given to areas of low species density (Table 6.8). This was to reduce direct disturbance by proposed facilities while located in sites close to potentially high wildlife viewing areas. High density areas were given the lowest score to reduce potential negative impacts from the facilities.

Table 6.8 Suitability scores for distance to wildlife hotspots

	Suitability score				
Reclassified densities	**All species**	**Browsers**	**Grazers***	**Mixed feeders**	**Rationale**
Low density	9	9	9	9	Areas with low species density are preferred over high density areas. There is good wildlife viewing with minimal negative impacts from the development.
High density	1	1	1	1	Areas with high species concentration have been given lower ranking to minimize any adverse impacts from the development. There is still game viewing potential in these areas.

*waterbuck density not included (see Chapter 5)

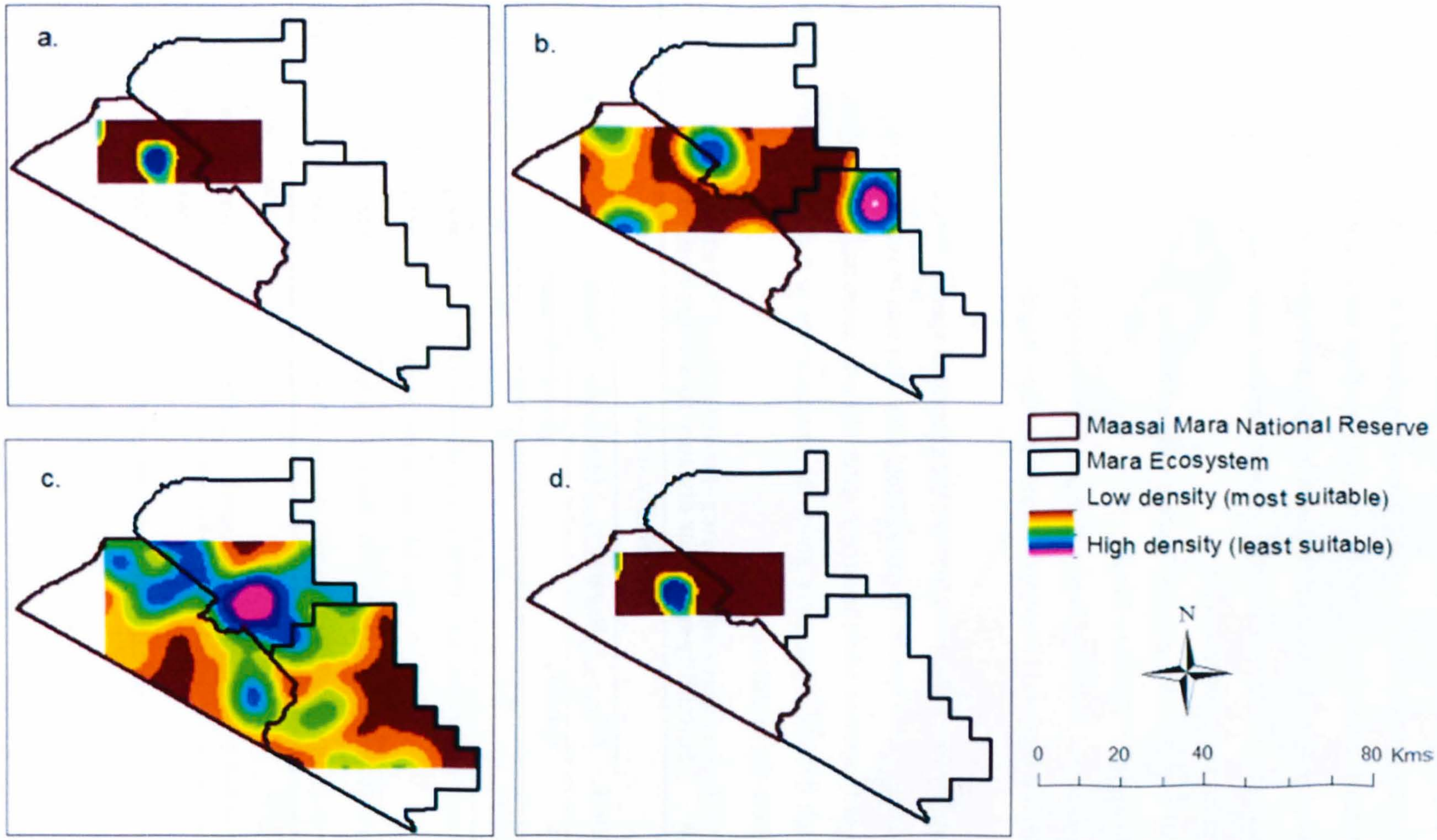

Figure 6.8 Hotspot areas for (a) all species, (b) browsers, (c) mixed feeders and (d) grazers

Distance to protected conservation area (Maasai Mara National Reserve)

The Maasai Mara National Reserve which covers 1 510 km^2 is the only gazetted protected area in the Mara Ecosystem, providing dry season grazing for migratory wildlife populations such as the wildebeest (Ottichilo *et al.*, 2000) consequently, land use within it is restricted to wildlife tourism (Thompson *et al.*, 2009). For maximum game viewing opportunities and reduced travel time, proposed tourist facilities should be sited within close proximity to the reserve but away from the settlements which are found along its boundaries.

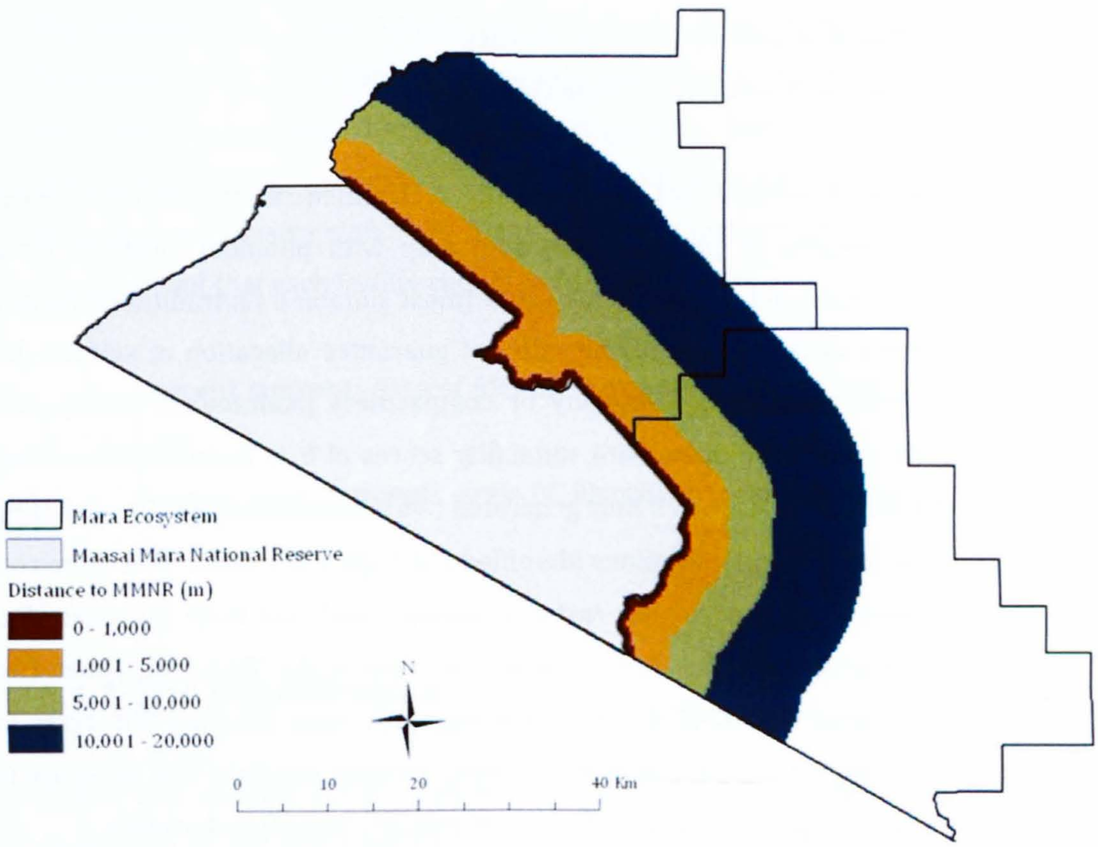

Figure 6.9 Distance from the protected area (Maasai Mara National Reserve)

Table 6.9 Suitability scores for distance from Maasai Mara National Reserve

Distance to MMNR (m)	Suitability score	Rationale
0-1000	9	Short distance travelled to get to the reserve for wildlife viewing
1001 - 5000	7	
50001 - 1000	4	Further to travel to reserve for game viewing – not acceptable to many tourists who expect wildlife close by
10001 - 20000	1	

6.4 Results

The following model scenarios were constructed to identify potential locations for future proposed developments.

i. Proximity to Maasai Mara National Reserve
ii. Proximity to existing infrastructure – transport links and rivers
iii. Proximity to existing tourist facilities
iv. Equal weighting for all selected parameters
v. Potential sites inside the protected area
vi. Potential sites in the group ranches
vii. Sites with potential wildlife viewing

The weighted overlay tool combined the reclassified rasters for each model using specified weights to produce an output map with potential locations rated on a suitability scale of 1 (least suitable) to 9 (most suitable). As traditional multi criteria approaches to land use suitability do not guarantee allocation of suitable locations with spatial patterns of contiguity or compactness (Malczewski, 2004), this study therefore considered areas with suitability scores of 8 as additional locations as the use of a suitability score of 9 only generated two suitable locations. Once all the models were run and potential locations identified, the high score raster cells were converted to polygons using the 'convert raster to polygon tool' and their areas calculated and converted to acres in the field calculator by running the VB Script; **[Area (Acres) = (Polygon area*0.000247)]**. Only locations with areas covering 500 acres or more were selected for consideration as locations covering less than 500 acres are not able to cater for ecofacilities under either of the two bed occupancy formulas.

The Mara Management Plan (Narok County Council and Trans Mara County Council, 2008) in its 10 year-implementation period (2008 – 2018), recommended no new lodges or expansion of new lodges be permitted in the MMNR. The plan further encouraged development of 'environmentally friendly facilities' to provide premium visitor accommodation and outlined the following requirements for proposed ecotourism facilities in the ecosystem:

- Eco-lodges to have a bed capacity of no more than 30 beds and have a 25 acre concession area
- Semi-permanent eco-camp (to be occupied for no more than nine months per year) with bed capacity of no more than 18 beds with a 12 acre concession area

During the course of this research, area occupied by individual lodges and camps in the ecosystem was recorded during visits to these lodges. The recorded areas were then used to calculate the average area occupied by each bed. An average 174 acres per bed (348 acres per tent) was calculated from a total area of 192501.1 acres occupied by 33 lodges, having a total of 1104 beds. This average was then used to calculate potential development size and comparisons made with development size computed by applying the conservancy concept which assigns 350 acres per bed (700 acres per tent) in order to achieve low density tourism and which is currently in use in some of the existing Mara conservancies (Grieves-Cook, 2010, Heath, 2010, Mara North Conservancy, 2011). To determine potential bed capacity for the locations selected by the suitability models, these two bed occupancy formulas were applied and a comparison of the two made. The number of beds calculated was then halved according to industry standards (two beds to a room) to determine the number of rooms or tent that each facility should have.

- **Current concept:** Area of identified location (acres) / 174 acres = Number of beds
- **Conservancy concept:** Area of identified location (acres) / 350 acres = Number of beds

6.4.1 Site identification

Taking into account the ten year moratorium imposed on lodge-sized developments (maximum of 200 beds) and bed capacity restrictions on other types of development by the Mara Management Plan, the seven suitability models identified several potential locations of varying sizes for future developments. Locations with <30 bed-capacity were selected as suitable for ecolodges and those with <18 bed-capacity were selected for ecocamps, with the smallest facility having a capacity of 6 beds (from existing camp sizes in the study area). Using the highest suitability criteria of 9, only two locations met the criteria and were selected as suitable for ecocamps. Locations that met the suitability scores of 8 were also selected with 43 potential locations suitable for ecocamps and 11 locations suitable for ecolodges. Locations with potential for larger lodge development were excluded in this selection. It should be noted that some of these locations have been selected as suitable by more than one model; a composite map (Figure 6.17) combining all these locations was therefore generated to identify areas in the ecosystem that are most suitable for proposed facilities. The most commonly identified locations were:

- Koiyaki, Lemek, Maji Moto and Ol Kinyei areas in the group ranches outside the protected area. Several conservancies have already been set up in these areas (Naboisho, Ol Kinyei, Motorogi, Olare Orok, Olchoro and Mara North) with most of them employing the 350 acres/bed formula to achieve low density tourism in these areas.
- Within the protected area, the Kurao, Elaui plains in the Mara Triangle and the Burungat plains on the Narok section of the Maasai Mara National Reserve were found to be the most suitable locations for future developments.

6.4.1.1 Proximity to the protected area

The MMNR is a gazetted wildlife area and serves as a dry season grazing ground for migrating ungulates and as a result, is popular with both tourists and developers. Any potential developments not constructed within the reserve's boundaries will therefore be looking for sites within easy reach to it. Taking this into account, this suitability model was used to identify sites close to the reserve, but situated away from human settlements and other tourist facilities which are likely to cause disturbance to tourists. Land cover was also included in this model.

Table 6.10 Weighting criteria for modelling locations close to the protected area

Layer	Weighting	Weighting criteria
Proximity to MMNR	40%	Locations closer to MMNR are more suitable
Proximity to human settlements	20%	Locations farthest from settlements more suitable
Proximity to tourist facilities	20%	Locations farthest from other lodges most suitable
Land cover	20%	Accessible areas with habitats least utilised by wildlife is preferred

*[(Proximity to MMNR*0.40)] + [(Distance to human settlements*0.20)] + [(Distance to existing tourist facilities*0.20)] + [(Land cover*0.20)]*

Table 6.11 **Recommended developments using the 'proximity to Maasai Mara National Reserve' suitability model**

SUITABILITY MODEL	SUITABILITY SCORE 9			SUITABILITY SCORE 8		
	Area (Acres)	Proposed facility size Beds (tents)†		Area (Acres)	Proposed facility size Beds (tents)†	
		Current concept	Conservancy concept		Current concept	Conservancy concept
Proximity to Maasai Mara National Reserve				1085.4	6 (3)**	3 (1)

Notes: †Each tent or room has two beds; *suitable location for ecolodge; ** suitable location for eco-camp

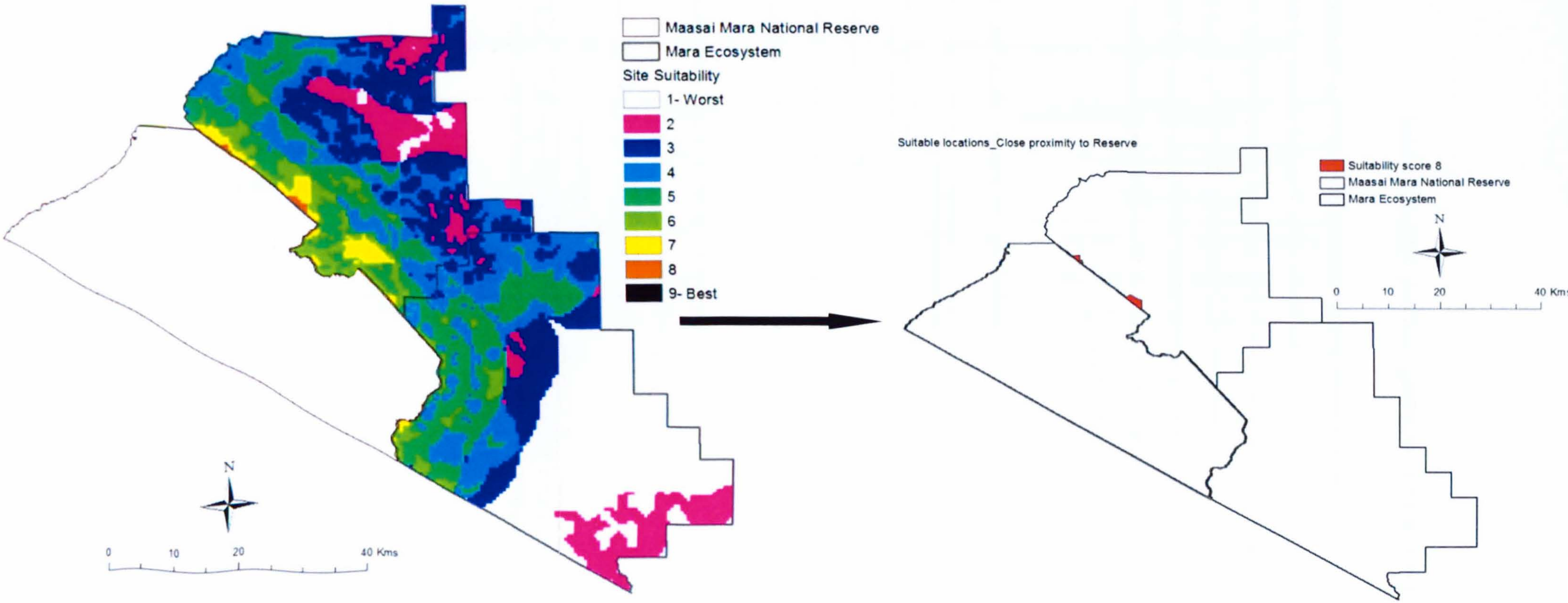

Figure 6.10 Suitable locations for new developments with proximity to Maasai Mara National as priority selection criteria

6.4.1.2 Proximity to existing tourism infrastructure

The second suitability model was developed to identify potential areas located in close proximity to existing infrastructure in the study area. Great distance to roads and airstrips involve extra costs in travel time and reduces accessibility for any new developments especially during construction. Constructing facilities too close to water bodies can increase the risk of flooding during heavy rains and maximize the likelihood of pollution by the tourist facility. The objective of this model was therefore to identify locations closest to existing infrastructure.

Table 6.12 Weighting criteria for modelling locations close to existing tourism infrastructure

Layer	Weighting	Weighting criteria
Accessibility to road network	25%	Proximity to roads more suitable
Proximity to airstrips	25%	Proximity to airstrip more suitable
Proximity to rivers	25%	Locations farthest from rivers most suitable
Proximity to human settlements	10%	Locations farthest from settlements more suitable
Proximity	10%	Locations farthest from other lodges most suitable
Land cover	5%	Accessible areas with habitats least utilised by wildlife is preferred

*[(Accessibility to roads*0.25)] + [(Proximity to airstrips*0.25)] + [(Proximity to rivers*0.10)] + [(Distance to human settlements*0.10)] + [(Distance to existing tourist facilities*0.10)] + [(Land cover*0.05)]*

Table 6.13 **Recommended developments using the 'proximity to existing tourism infrastructure' suitability model**

SUITABILITY MODEL	SUITABILITY SCORE 9			SUITABILITY SCORE 8		
	Area (Acres)	Proposed facility size Beds (tents)†		Area (Acres)	Proposed facility size Beds (tents)†	
		Current concept	Conservancy concept		Current concept	Conservancy concept
Proximity to existing tourism infrastructure	500	3 (1)	1 (1)	2283.6	13 (6)**	7 (3)**
	618.3	4 (2)	2 (1)	1444.5	8 (4)**	4 (2)
				612.6	4 (2)	2 (1)

Notes: †Each tent or room has two beds; *suitable location for ecolodge; ** suitable location for eco-camp

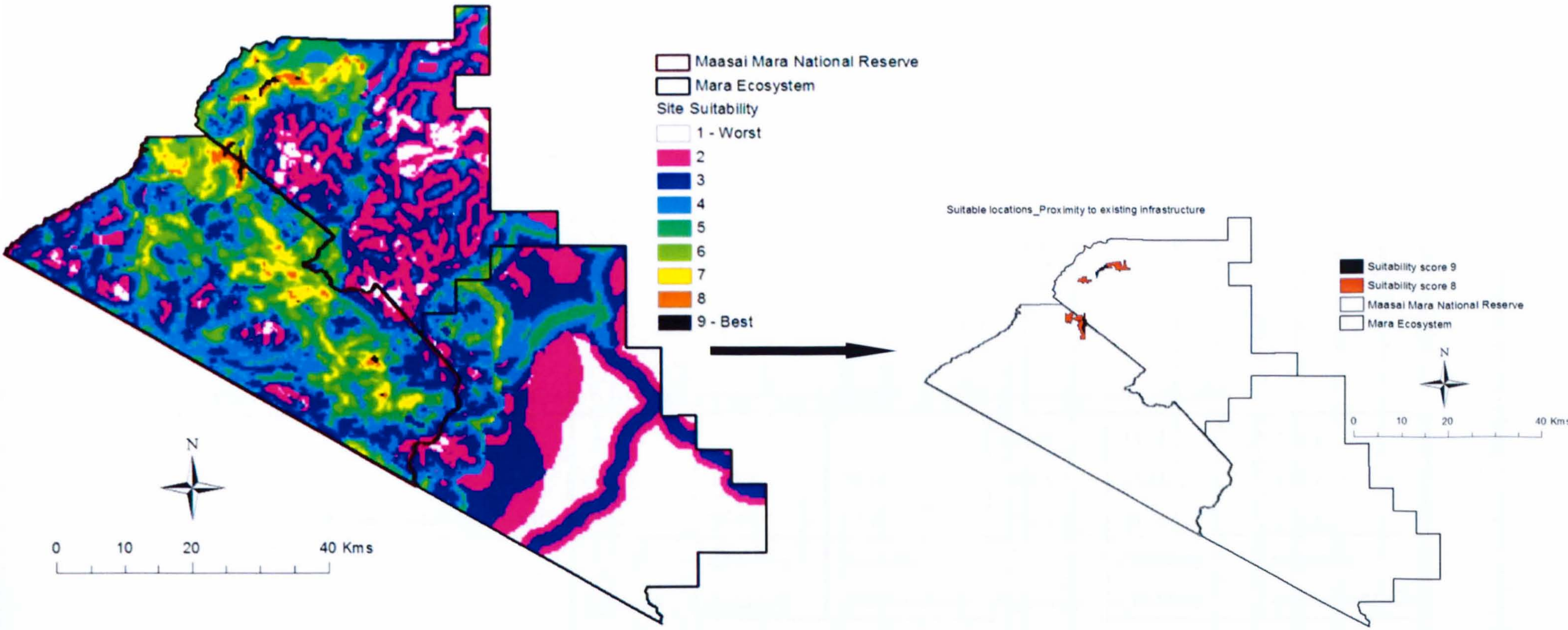

Figure 6.11 Suitable locations for new developments with proximity to existing tourism infrastructure (Roads + rivers + airstrips) as priority selection criteria

6.4.1.3 Proximity to existing tourist facilities

Tourism developers prefer secluded locations for new camps to maximize visitor experience and reduce disturbance from neighbouring lodges. This suitability model was developed to identify potential locations for proposed facilities giving high weighting to areas further away from existing tourist facilities. Also included in this suitability model were proximity to the National Reserve, land cover, proximity to settlements and presence of water sources.

Table 6.14 Weighting criteria for modelling locations furthest from existing tourist facilities

Layer	Weighting	Weighting criteria
Proximity to existing tourist facilities	40%	Locations farthest from other lodges most suitable
Proximity to human settlements	20%	Locations farthest from settlements more suitable
Proximity to rivers	10%	Locations farthest from rivers most suitable
Proximity to MMNR	10%	Locations closer to MMNR are more suitable
Land cover	20%	Accessible areas with habitats least utilised by wildlife preferred

*[(Distance to existing tourist facilities*0.40)] + [(Proximity to rivers*0.10)] + [(Distance to human settlements*0.10)] + [(Proximity to MMNR*0.05)] + [(Land cover*0.05)]*

Table 6.15 Recommended developments using the 'proximity to existing tourist facilities' suitability model

SUITABILITY MODEL	SUITABILITY SCORE 9			SUITABILITY SCORE 8		
	Area (Acres)	Proposed facility size Beds (tents) †		Area (Acres)	Proposed facility size Beds (tents)†	
		Current concept	Conservancy concept		Current concept	Conservancy concept
Proximity to existing tourist facilities	526.9	3 (1)	1 (1)	19794.2	114 (52)	57 (28)
				8501.8	49 (24)	24 (12)*
				5409.7	31 (15)*	15 (7)**
				4317.5	25 (12)*	12 (6)**
				1777.2	10 (5)**	5 (2)
				1410.2	8 (4)**	4 (2)
				930.9	5 (2)	3 (1)
				797.6	5 (2)	2 (1)
				783.6	5 (2)	2 (1)
				782.5	4 (2)	2 (1)
				759.5	4 (2)	2 (1)

Notes: †Each tent or room has two beds; *suitable location for ecolodge; ** suitable location for eco-camp

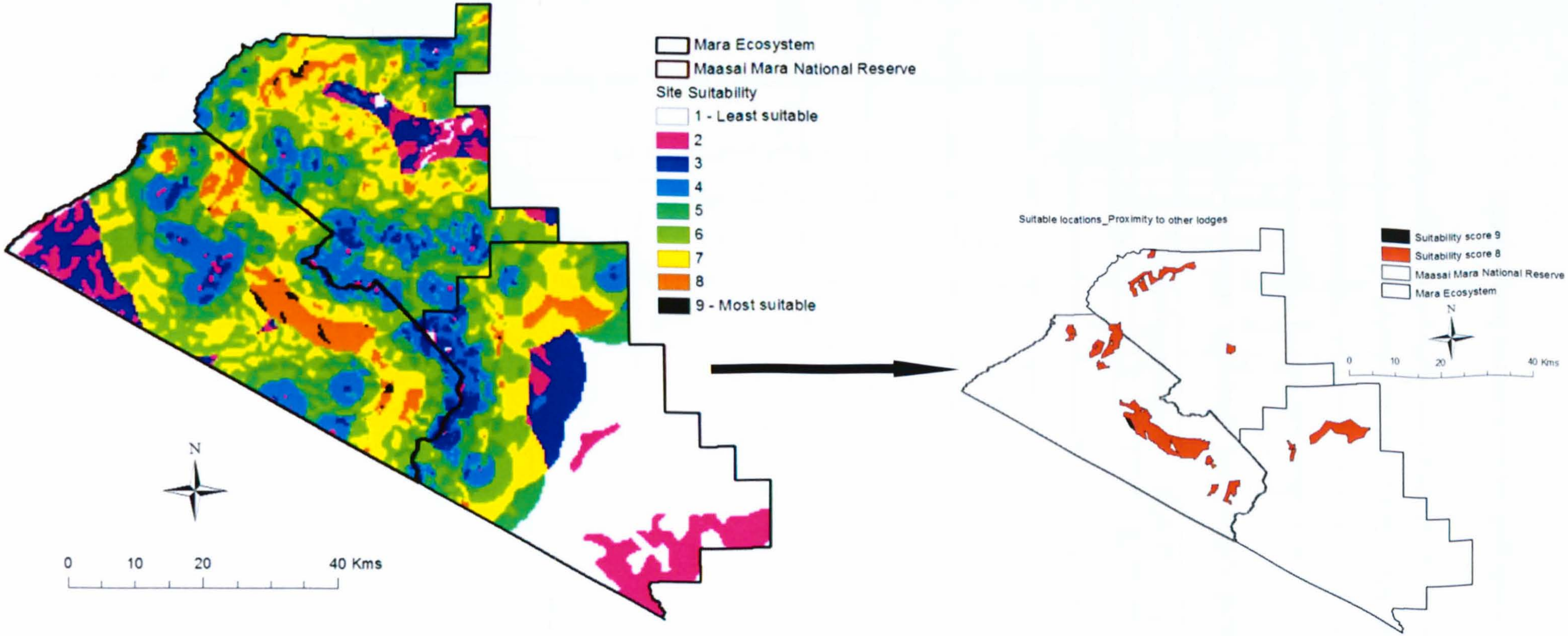

Figure 6.12 Suitable locations for new developments with proximity to existing tourist facilities as priority selection criteria

6.4.1.4 Equal weighting for all selected parameters

The fourth suitability model designated equal weighting to all the selected parameters to give them equal influence in the model. Accessibility to infrastructure (distance to roads + distance to rivers + distance to airstrip) was separately weighted and applied to the model as one layer as the weighted overlay tool add five rasters at each run.

Table 6.16 Weighting criteria for modelling locations using all selected variables

Layer	Weight	Weighting criteria
Proximity to MMNR	20%	Locations closer to MMNR are more suitable
Accessibility to infrastructure	20%	Proximity to roads more suitable
Proximity to human settlements	20%	Locations farthest from settlements more suitable
Proximity to existing tourist facilities	20%	Locations farthest from other lodges most suitable
Land cover	20%	Accessible areas with habitats least utilised by wildlife preferred

*[(Distance to existing tourist facilities*0.20)] + [(Accessibility to infrastructure*0.20)] + [(Distance to human settlements*0.20)] + [(Proximity to MMNR*0.20)] + [(Land cover*0.20)]*

Table 6.17 Recommended developments using the 'equal weighting for all selected parameters' suitability model

SUITABILITY MODEL	SUITABILITY SCORE 9			SUITABILITY SCORE 8		
	Area (Acres)	Proposed facility size Beds (tents)†		Area (Acres)	Proposed facility size Beds (tents)†	
		Current concept	Conservancy concept		Current concept	Conservancy concept
Equal weighting for all selected parameters				22225.8	128 (64)	64 (32)
				9382.9	54 (27)	27 (13)*
				2964.2	17 (8)**	8 (4)**
				2656.1	15 (7)**	8 (4)**
				1876.4	11 (5)**	5 (2)
				618.2	4 (2)	2 (1)

Notes: †Each tent or room has two beds; *suitable location for ecolodge; ** suitable location for eco-camp

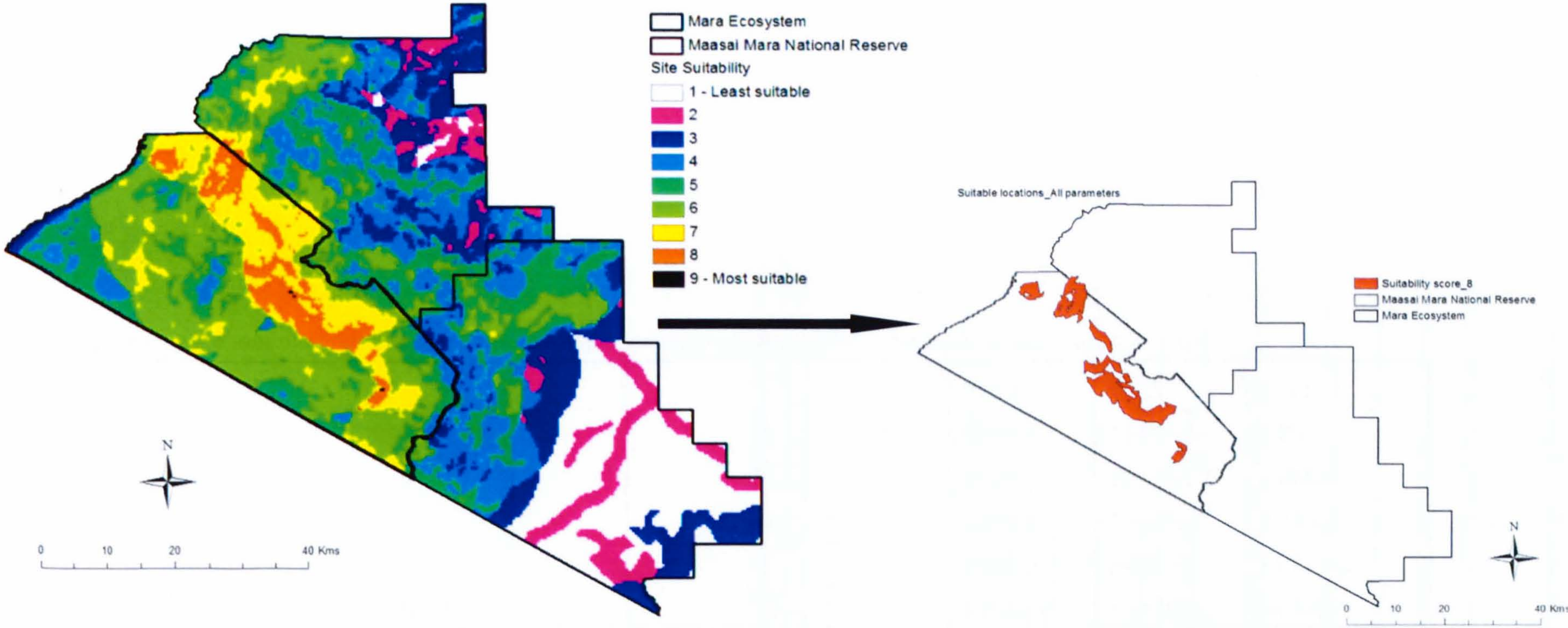

Figure 6.13 Suitable locations for new developments giving all parameters equal weighting

6.4.1.5 Suitable locations in the protected area

A fifth model was run to identity potential new lodge sites within the national reserve. This model therefore excluded the 'distance to settlements' and 'distance to MMNR' parameters. This is because all human settlements occur outside the reserve and would have no influence the model. There are only two airstrips in the reserve and inclusion of this parameter would restrict the model. Included are distance to other tourist facilities, roads, rivers and land cover which were given equal weighting.

Table 6.18 Weighting criteria for modelling locations inside the protected area

Layer	Weight	Weighting criteria
Accessibility to road network	25%	Proximity to roads more suitable
Proximity to rivers	25%	Locations farthest from rivers most suitable
Proximity to existing tourist facilities	25%	Locations farthest from other lodges most suitable
Land cover	25%	Accessible areas with habitats least utilised by wildlife preferred

*[(Proximity to roads*0.25)] + [(Proximity to rivers*0.25)] + [(Proximity to tourist lodges*0.25)] + [(Land cover*0.25)]*

Table 6.19 Recommended developments using the 'suitable locations in the protected area' suitability model

SUITABILITY MODEL	SUITABILITY SCORE 9			SUITABILITY SCORE 8		
	Area (Acres)	Proposed facility size Beds (tents)†		Area (Acres)	Proposed facility size Beds (tents)†	
		Current concept	Conservancy concept		Current concept	Conservancy concept
Suitable locations in the protected area				2080.2	12 (6)**	6 (3)**
				1492.9	9 (4)**	4 (2)
				1444.8	8 (4)**	4 (2)
				1379	8 (4)**	4 (2)
				1285.5	7 (3)**	4 (2)
				1186.1	7 (3)**	3 (1)
				1093.3	6 (3)**	3 (1)
				1055	6 (3)**	3 (1)
				990.5	6 (3)**	3 (1)
				812.2	5 (2)	2 (1)
				711.6	4 (2)	2 (1)
				531.2	3 (1)	2 (1)
				507.8	3 (1)	1 (1)

Notes: †Each tent or room has two beds; *suitable location for ecolodge; ** suitable location for eco-camp

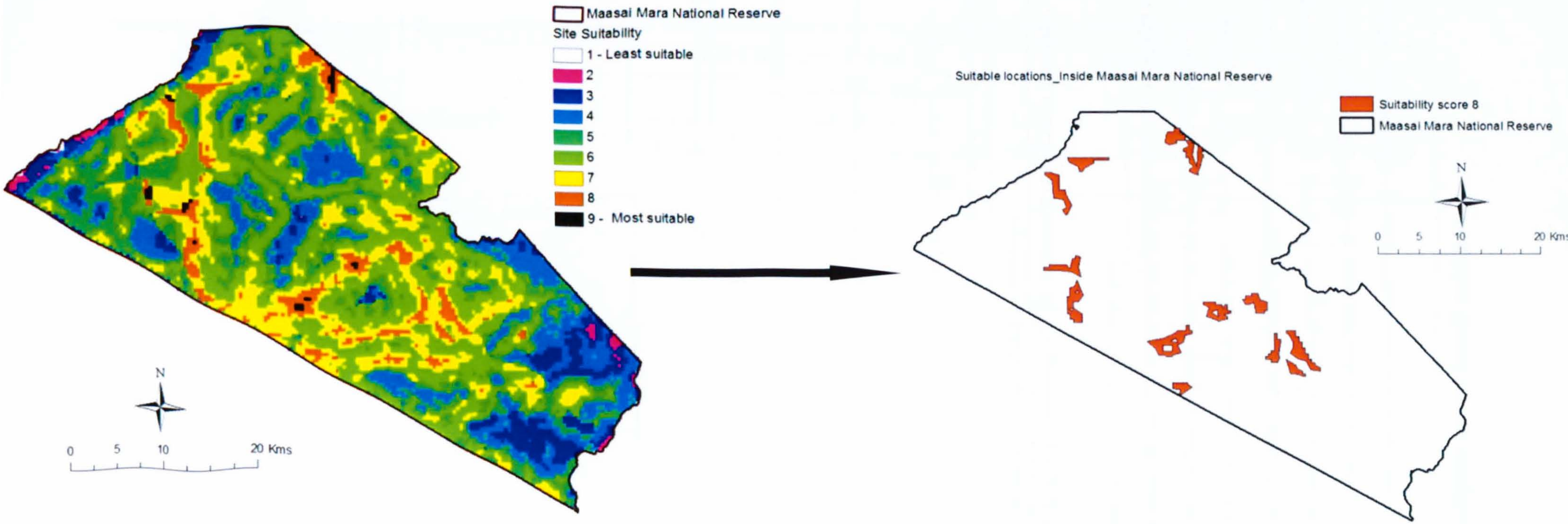

Figure 6.14 Suitable locations for new developments within the protected area (Maasai Mara National Reserve)

6.4.1.6 Suitable locations in the group ranches

A sixth model was run to identity potential new lodge sites away from the national reserve. With the growing number of conservancies in the ecosystem, development pressure in and around the national reserve will be reduced as wildlife viewing becomes more available in the ranches. This model therefore excluded the 'distance to MMNR' parameter. Distance to roads and airstrips were also excluded as infrastructure is not well developed outside the protected area. Land cover and distance from other facilities were given the highest weightings as most of the land use changes in the Mara ecosystem have been in the ranches.

Table 6.20 Weighting criteria for modelling locations in the group ranches

Layer	Weight	Weighting criteria
Proximity to rivers	10%	Locations furthest from rivers most suitable
Proximity to existing tourist facilities	40%	Locations furthest from other lodges most suitable
Proximity to human settlements	10%	Locations furthest from human settlements preferred.
Land cover	40%	Accessible areas with habitats least utilised by wildlife preferred

*[(Proximity to rivers*0.10)] + [(Distance to human settlements*0.10)] + [(Proximity to tourist facilities*0.40)] + [(Land cover*0.40)]*

Table 6.21 Recommended developments using the 'suitable locations in the group ranches' suitability model

SUITABILITY MODEL	SUITABILITY SCORE 9			SUITABILITY SCORE 8		
	Area (Acres)	Proposed facility size Beds (tents)†		Area (Acres)	Proposed facility size Beds (tents)†	
		Current concept	Conservancy concept		Current concept	Conservancy concept
Suitable locations in the group ranches	1164.6	7 (3)**	3 (1)	24129.3	139 (69)	69 (34)
				13322.5	77 (38)	38 (19)
				9772.1	56 (28)	28 (14)*
				2387.7	14 (7)**	7 (3)**
				2271.2	13 (6)**	6 (3)**
				1893.1	11 (5)**	5 (2)
				1141.8	7 (3)**	3 (1)
				1066.6	6 (3)**	3 (1)
				1013.2	6 (3)**	3 (1)
				902.2	5 (2)	3 (1)
				834	5 (2)	2 (1)
				725.2	4 (2)	2 (1)
				675.6	4 (2)	2 (1)
				640.9	4 (2)	2 (1)
				608.9	3 (1)	2 (1)
				515.8	3 (1)	1 (1)

Notes: †Each tent or room has two beds; *suitable location for ecolodge; ** suitable location for eco-camp

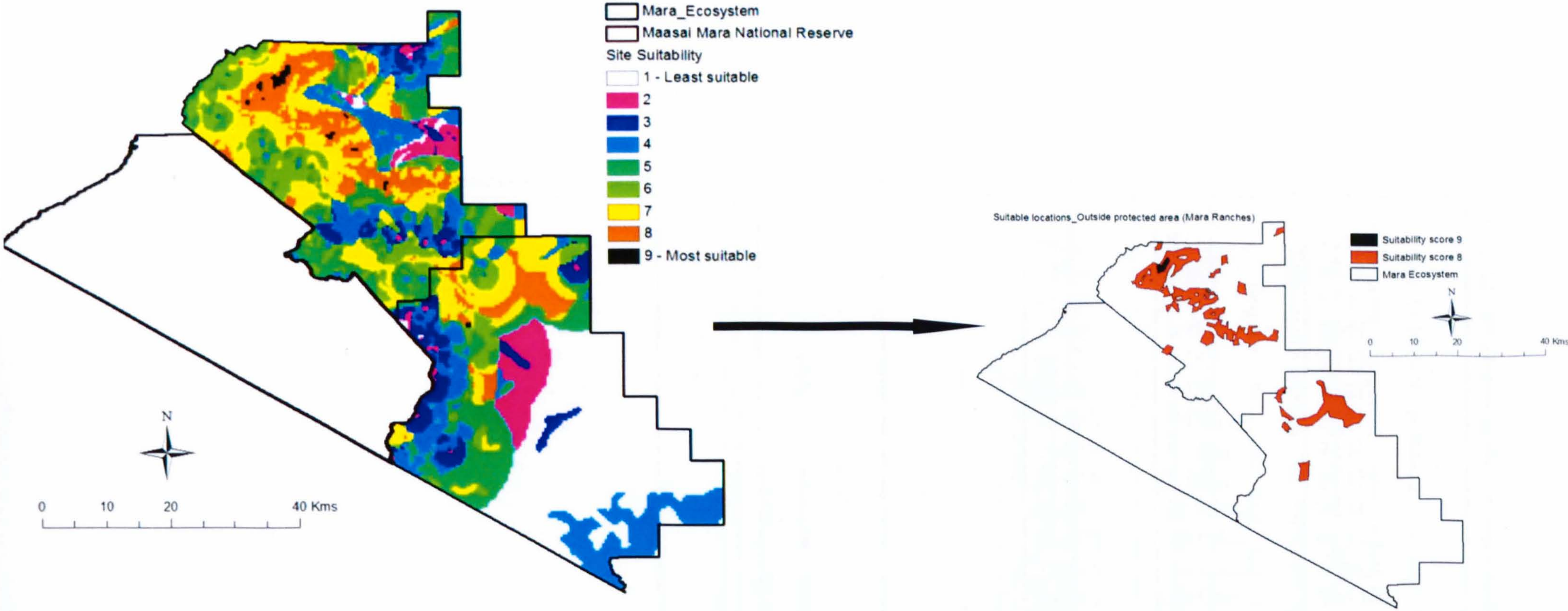

Figure 6.15 Suitable locations for new developments in the non-protected area (group ranches)

6.4.1.7 Locations with good wildlife viewing

A final model was run to identity potential sites for new lodges near wildlife hotspots to provide good viewing potential reserve. This model created 4 maps for each of the dietary guilds (Figure 6.6) which were given highest weights and included all the other parameters except proximity to MMNR which were given equal weight.

Table 6.22 Weighting criteria for modelling locations with good wildlife viewing

Layer	Weight	Weighting criteria
Wildlife hotspots [1,2,3,4]	40%	Areas close to wildlife hotspots are preferred
Accessibility to infrastructure	15%	Proximity to roads more suitable
Proximity to human settlements	15%	Locations farthest from settlements more suitable
Proximity to existing tourist facilities	15%	Locations farthest from other lodges most suitable
Land cover	15%	Accessible areas with habitats least utilised by wildlife preferred

[1] *[(Distance to all species hotspots*0.40)] + [(Accessibility to infrastructure*0.15)] + [(Distance to human settlements*0.15)] + [(Proximity to tourist facilities*0.15)] + [(Land cover*0.15)]*

[2] *[(Distance to browser hotspots*0.40)] + [(Accessibility to infrastructure*0.15)] + [(Distance to human settlements*0.15)] + [(Proximity to tourist facilities*0.15)] + [(Land cover*0.15)]*

[3] *[(Distance to all grazer hotspots*0.40)] + [(Accessibility to infrastructure*0.15)] + [(Distance to human settlements*0.15)] + [(Proximity to tourist facilities*0.15)] + [(Land cover*0.15)]*

[4] *[(Distance to mixed feeder hotspots*0.40)] + [(Accessibility to infrastructure*0.15)] + [(Distance to human settlements*0.15)] + [(Proximity to tourist facilities*0.15)] + [(Land cover*0.15)]*

Table 6.23 Recommended developments using the 'locations with good wildlife viewing' suitability model

SUITABILITY MODEL	SUITABILITY SCORE 9			SUITABILITY SCORE 8		
		Proposed facility size Beds (tents)†			Proposed facility size Beds (tents)†	
Locations with good wildlife viewing	Area (Acres)	Current concept	Conservancy concept	Area (Acres)	Current concept	Conservancy concept
All species	967.2	6 (3)**	3 (1)	8855.2	51 (25)	25 (12)*
				7992.2	46 (23)	23 (11)*
				4199.6	24 (12)*	12 (6)**
				1245.6	7 (3)**	4 (2)
Browsers				46378.6	267 (133)	133 (66)
				2352.3	14 (7)**	7 (3)**
				753.2	4 (2)	2 (1)
				651.4	4 (2)	2 (1)
Grazers	524.8	3 (1)	1 (1)	8297.9	48 (24)	24 (12)*
				6650.4	38 (19)	19 (9)**
				4810.9	28 (14)*	14 (7)**
				3143.2	18 (9)**	9 (4)**
				708.2	4 (2)	2 (1)
				639.8	4 (2)	2 (1)
Mixed feeders	14014.5	81 (40)	40 (20)	50247	289 (144)	144 (12)*
	795.7	5 (2)	2 (1)	13004.6	75 (37)	37 (18)
				6471.2	37 (18)	18 (9)**
				5944.5	34 (17)	17 (8)**
				1788.2	10 (5)**	5 (2)
				1274.5	7 (3)**	4 (2)
				802.3	5 (2)	2 (1)
				795.7	2 (1)	2 (1)

Notes: †Each tent or room has two beds; *suitable location for ecolodge; ** suitable location for eco-camp

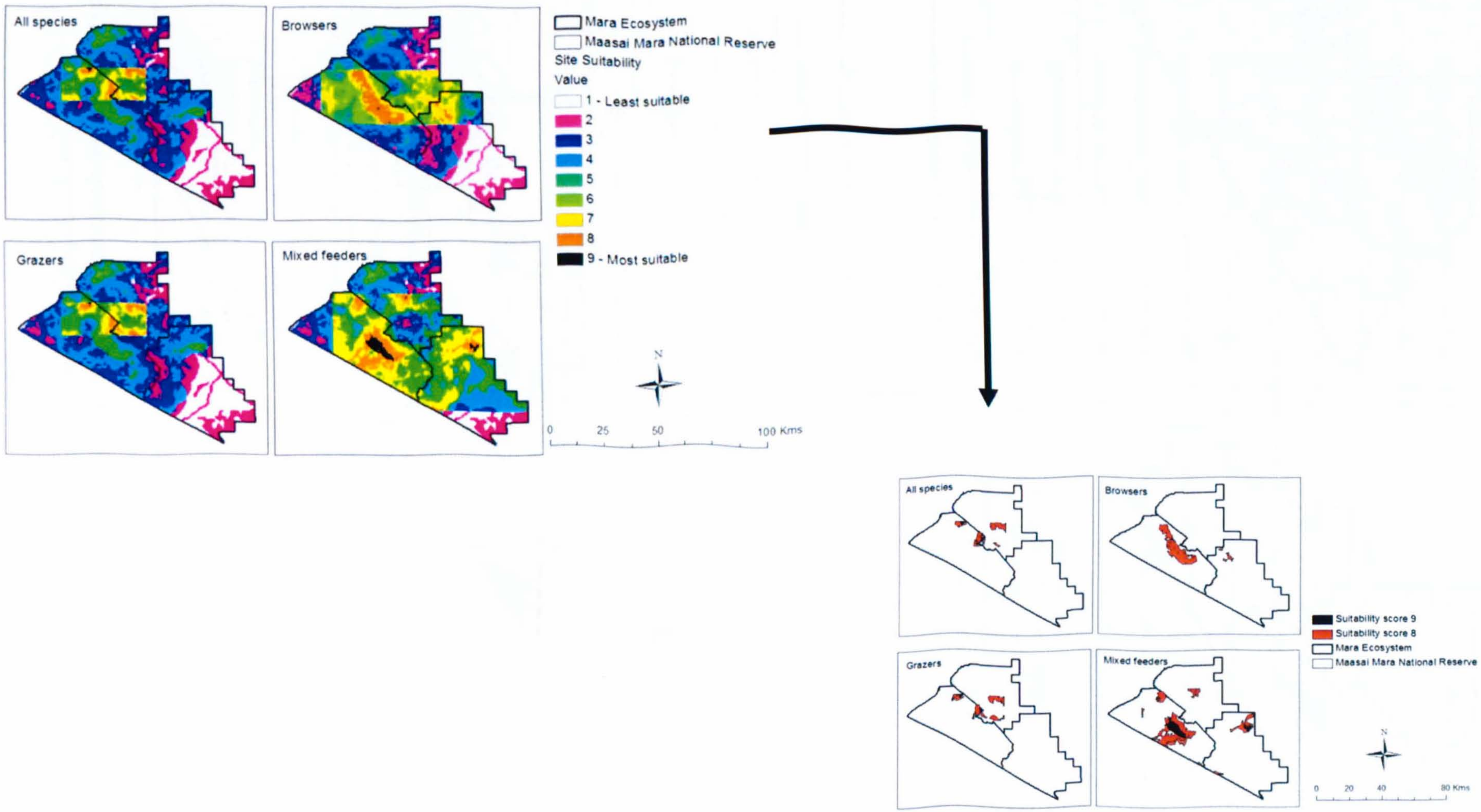

Figure 6.16 Suitable locations for new developments giving priority to all hotspot areas according to feeding guilds

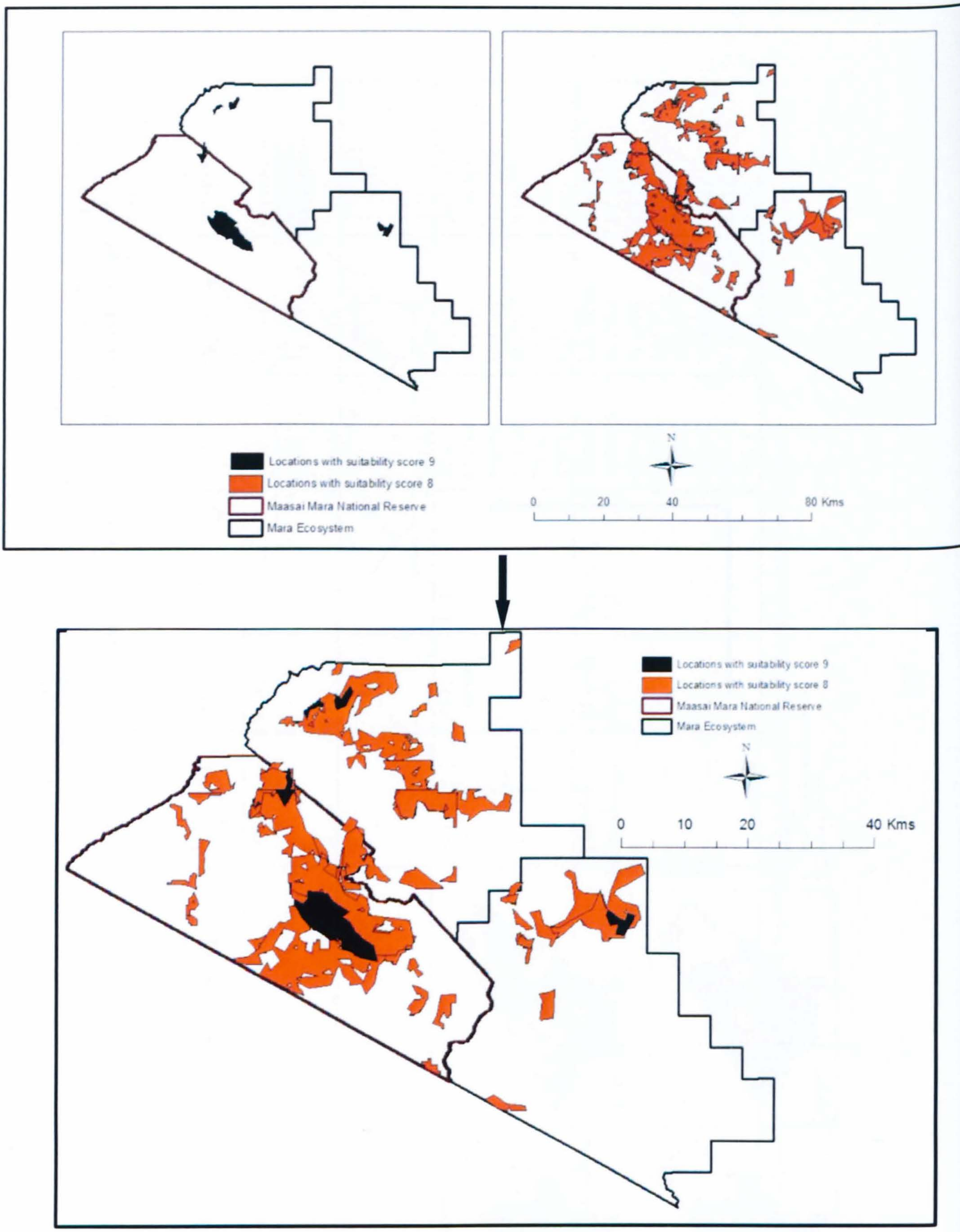

Figure 6.17 Maps showing locations with different suitability scores with a final composite map incorporating all model scenarios

6.5 Discussion

GIS systems have increasingly come to be identified as important tools in land use suitability mapping and modelling given their capability for supporting decision making processes (Malczewski, 2004). Using MCDA, site selection models aimed to identify the best locations for a given activity by applying a ranking scale based on known characteristics and attributes of the study site. However, there is no widely accepted method for assigning weights of relative importance to criterion maps making it highly likely that different weighting methods will result in different land use suitability patterns (Malczewski, 2004). Applying these principles to this research, several models were constructed and different weights assigned to selected site attributes according to model priority and suitable locations for future ecotourism developments identified. These locations were then combined to create a composite map to highlight the most suitable areas for future tourism developments in the Mara Ecosystem.

The increased interest in the Mara as a tourism destination has witnessed growth in the number of tourist facilities with a current estimate of 4000 beds (Ringa, 2010) with 910 of these located within the MMNR. Using the two bed-occupancy models to determine the available bed-space in the Mara Ecosystem's for potential developments, the following projections were made:

Table 6.24 Potential and available bed-occupancies in the Mara Ecosystem

BED OCCUPANCY MODEL	Potential capacity (beds)			Available capacity (beds)		
	ME	MMNR	MR	ME	MMNR	MR
Current concept (174 acres/bed)	6353	2153	4200	2353	1243	1110
Conservancy concept (350 acres/bed)	3159	1070	2089	-	160	-

Notes: ME – Mara Ecosystem (1105497.9 acres), MMNR – Maasai Mara National Reserve (374550.8 acres, MR – Mara Ranches (730947.1 acres)
Available bed capacity (for future developments) = Potential capacity - current capacity

According to the conservancy model which seeks to protect the environment and wildlife by controlling the number of developments and limiting the number of tourist vehicles in a given area, the MMNR has potential for 160 beds, which may be because of the strict development controls in place, but indicates that the greater ecosystem has exceeded its carrying capacities, suggesting that no more developments be constructed in the ecosystem. The current bed-occupancy concept however demonstrates that there is still development potential both in both the reserve and ranches. However, these bed numbers are not conclusive as the two bed occupancy models are not consistently applied across the whole ecosystem and have been used in this research as current industry indicators. Presently, tour operators consider distance to permanent water sources and proximity to the reserve as priority criteria when selecting suitable locations for new facilities in the ecosystem (Pers. Comm.). Subsequently, many of the existing tourist facilities are constructed along the Mara and Talek River, resulting in overdevelopment, particularly along the reserve's northern boundaries, and underdevelopment in areas further away from the reserve. The proliferation of tourist camps and lodges along these two rivers have further raised concerns about their impact on the annual wildebeest crossings which occur along these rivers, with calls for no further developments to be constructed along these rivers.

Although the resulting suitability models point toward potential for further development of ecolodges and or ecocamps in the Maasai Mara National Reserve, this research discourages it based on the results of the analysis of ungulate response to developments (Chapters 4 & 5) which demonstrate that some species react negatively to overdevelopment. This view is supported by wildlife managers who argue that continued developments in the protected area are detrimental to the ecological integrity of the reserve and the future of its wildlife because of the existing high visitor use pressures originating from outside the MMNR (Narok County Council and Trans Mara County Council, 2008). It is recommended that any proposed tourist facilities be located outside the reserve to utilise the Greater Mara Ecosystem. While the increasing number of tourists visiting the Mara need to be accommodated by constructing more facilities, ecological principles should be observed when selecting locations. In addition the suitability models must be considered alongside scientific evidence of the impacts of pressures on the Mara's river system, the utilisation of the selected location by tourist vehicles from existing facilities, and the impact of increased livestock numbers in the ecosystem which compete with wildlife for water and forage in the dry season (Ottichilo et al., 2000, Ogutu et al., 2011). It is also important to consider the current land uses in this ecosystem (increased subsistence and mechanized agriculture) and the growing human population which further reduces the amount of land available for wildlife tourism. Both these may influence the ultimate decision on a location's suitability.

The successful use of a GIS to select locations for potential tourist facilities in a wildlife area requires complete, up-to-date, spatial data for the study area in order to produce the most useful results. This research used the most current high resolution data available for the Mara Ecosystem, but acknowledges the lack of complete spatial and temporal datasets, especially in the group ranches, which left some sections of the ecosystem untested. Incorporation of Geographical Information Systems to record and store spatial and temporal data into the implementation of the ecological monitoring programme that has been proposed in the Mara Management Plan will allow for more rigour in the site selection process.

During the course of this research, a GIS database was created comprising ungulate species densities and distributions over a twenty year period, habitat classes as well as anthropogenic and natural features of the Mara Ecosystem. This database, the resulting suitability models and composite maps are to be made available to the relevant decision making authorities to allow them make decisions on any future tourism developments for the Mara Ecosystem especially within the protected area. As the suitability models created from this research are easily modified, they can be tailored to suit different scenarios in other wildlife areas. It is therefore hoped that this study's results will influence policy direction in terms of tourism planning in wildlife areas for this and other ecosystems in the region.

Chapter 7

CONCLUSION

7.1 Introduction

Wildlife based tourism in Kenya began at the end of the 19th Century and increased in popularity in the 1930s when hunting safaris became popular. In 1947, Nairobi National Park was gazetted as Kenya's first protected area, and set aside exclusively for the use of wildlife (Gichohi, 2003). Since then, the number of protected areas in the country has grown to over 60, covering 8% of the country's land surface (Western *et al.*, 2009). Similarly, wildlife tourism in Kenya has steadily grown, especially in the last ten years, with a significant rise in the number of tourists arriving into the country (Ministry of Tourism and Wildlife, 2011), leading to an increase in tourist facilities within wildlife parks and reserves to accommodate these visitors. The resulting negative environmental impacts associated with wildlife tourism's supporting infrastructure such as buildings, roads and airstrips identified the need for sustainable tourism in the country and subsequently, led to the growth of ecotourism. Kenya's earliest ecotourism ventures were initiated around national reserves such as Amboseli, Maasai Mara and on private ranches, with the success of Il Ngwesi lodge, the first community owned ecolodge, in Laikipia District, precipitating the establishment of similar ventures in the region including Shompole lodge in Kenya, Tarangire Company in Tanzania and Uganda's Buhoma Rest Camp in Bwindi Forest (Okech, 2009). While ecotourism in Kenya has been deemed a success, the very attraction on which it is based, wildlife is severely threatened.

Kenya's tourism industry faces specific threats which may influence future tourist numbers. These include corruption, recurrent ethnic conflicts, and external tourism threats leading to travel advisories as well as increased carbon off-set costs which increase travel costs. The indirect effects of habitat destruction and alteration, mainly caused by human activities, including ecotourism (Lado, 1992) are currently viewed as a serious long-term threat to Kenya's wildlife populations, and ultimately its tourism industry. Like other protected ecosystems, the Mara Ecosystem is no exception to the pressures of increased human population and urbanisation which increase cases of human-wildlife conflicts, agricultural expansion and growth in tourism. Its wildlife populations are constantly facing survival challenges, calling for quick and concerted efforts by wildlife managers and policy makers if they are to remain ecologically sustainable. Tourism's impacts on wildlife therefore need to be appraised and presented against an ecological background, where affected areas are assessed using existing baseline data (species life history parameters, habitat requirements, natural movements and social behaviour) overlaid by their responses to the industry's activities (Rodger and Moore, 2004). Additionally, the use of scientific methodology to assess and mitigate wildlife tourism's negative ecological impacts should be explored. With this in mind, this research assessed the impacts of tourist developments to wildlife in the Mara Ecosystem, and addressed three major aims:

i. An examination of the anthropogenic impacts of different wildlife tourism developments (eco-facilities and traditional lodges) on key ungulate species in the Mara Ecosystem.

ii. Analysis of species spatial density and distribution patterns in relation to tourism growth in the ecosystem over a twenty year period (1990 - 2010).

iii. The development of a site suitability selection model in a GIS to identify the best locations for proposed tourist developments.

7.2 Species response to tourist facilities

The 1977 border closure between Kenya and Tanzania caused a sharp rise in visitor numbers to the Mara section of the greater Mara-Serengeti Ecosystem, with more visitors than before visiting the Maasai Mara National Reserve, triggering inadequately planned ecotourism developments and infrastructure to cater to the increased tourist numbers. This was further compounded by the government imposed hunting ban later that year, which eliminated income to surrounding group ranches causing many ranchers to shift to wildlife-viewing tourism and even more lodge and tented camp construction. By 1987, about half the tourism developments in the Mara were in the wildlife dispersal areas which largely consisted of community owned ranches (Honey, 2009, Watkin, 2002). While the Maasai Mara receives more visitors than any other wildlife area in East Africa and about half of the tourists visiting Kenya today, it also reveals how the struggles over land, wildlife and tourism revenues can undermine ecotourism's underlying aspirations (Honey, 2009). A main objective of this research was therefore to investigate the anthropogenic impacts of different wildlife tourism developments (ecolodges and traditional lodges) upon key ungulate species in the Mara Ecosystem, taking into account the nature of disturbance, habitat types and the season (high and low tourism seasons) during which the disturbance occurred.

Using descriptive statistics for initial data analysis, most of the study species were noted to have on average a higher tolerance to eco-lodges (mean distance of 266.8m) than traditional lodges (447.03m) which may in part be due to the non-intrusive nature of ecotourism. However, the Kruskal-Wallis one-way ANOVA was run for more in-depth analysis of the relationship and it was determined that there were significant differences in the distance to developments by Buffalo, Topi, Giraffe, Impala, Thompson's gazelle and Zebra. The test was further run to test for differences in species group sizes around the two development types and revealed no significant difference for species group size with the exception of Buffalo; typically buffalo occur in large mixed herds of up to 500 animals and strongly compete with cattle for pasture and prefer to be close to tourist facilities where the presence of cattle is controlled by lodge management and water is more readily available. The test was also used to consider differences in species group sizes and distance around the different tourist development types between the two tourism seasons, with significant differences noticeable in Topi and Grant's gazelle group sizes and Buffalo and Impala distances from the lodges across the tourism seasons. The remaining study species did not appear to be significantly influenced by seasonal differences. These results confirm suppositions made that tourism impacts are species specific (Hidinger, 1999, Theobald *et al.*, 1997), with Buffalo, Topi and Impala observed as the species most affected by the presence of tourist facilities. This corresponds with previous research which shows that effects of the tourism industry, especially tourists, on wildlife are species specific.

According to Whittaker and Knight (1998), different species have developed situation-specific responses, a combination of learning and genetics, which have in turn made them successful in their survival. However as the human–wildlife interface changes, some of these responses may become detrimental to the wildlife or lead to increased conflicts with people. Habituated animals do not avoid contact with humans or those areas where contact is likely, such as tourist facilities, resulting in ecological problems. Areas with human-habituated wildlife may exhibit 'refuge effect' where the wildlife are attracted to artificially watered grounds for food and receive artificial protection against predators (Kloppers et al., 2005), which generally tend to avoid built up areas. This can lead to changes in natural predator-prey relationships and cause artificial population growth of certain species, which in turn lead to ecological imbalance such as long-term changes in the floristic makeup of the area or changes in herbivore densities which subsequently affect predator numbers and distribution (Hidinger, 1999). During this research, habituation was observed among several wildlife species mostly around older tourism establishments which had higher wildlife concentrations, with Bushbuck (*Tragelaphus scriptus)* and Impala frequently sighted in high numbers around these facilities. Eland displayed more avoidance behaviour than any other study species and were rarely sighted around tourist facilities.

Ecotourism in the Mara Ecosystem, and Kenya as a whole, is gaining popularity and while it has been shown to play an important role in environmental conservation through recycling of solid waste, grey and black water and the use of alternative energy sources, its impacts on local wildlife species are still significant when comparisons are made between eco-rated and non eco-rated tourist facilities as evidenced by this research. Relatively minor human–induced disturbances from both the eco-rated and non eco-rated facilities which may be overlooked, have been shown to impact on the viability of wildlife populations in protected areas through changes in their social structures and physiological responses. Consequently, this has direct significance on how evaluations and assessments of sustainable levels of human disturbances in these areas are carried out and furthermore influence management design of suitable options for tourist activities in these protected areas (Kerbiriou *et al.*, 2009). This research reinforces previous work that there is urgent need for more integrative approaches to combine research at individual species and population levels. This might be achieved using population dynamic models to project how human disturbance will influence species populations under different tourism scenarios. Further work is therefore needed to complement this research through the collection of species disturbance data from other sources beside tourist developments, such as hot air balloon safaris, livestock grazing in the protected area, poaching and encroaching human settlements, to investigate wildlife response and population changes resulting from these disturbances. Without this level of ecological understanding, wildlife areas like the Maasai Mara National Reserve will likely continue to decline leading to a reduction in tourist interest in such areas.

7.3 Long term ungulate response in a changing landscape

It has been widely reported that global extinction of many wildlife species is thought to be caused by habitat fragmentation or complete habitat loss in wildlife rangelands. The conversion of wildlife rangelands to agriculture and livestock ranching is of great concern to wildlife managers in Kenya (Ottichilo *et al.*, 2000). Wildlife decline in the Mara Ecosystem and threats to the long term viability of its wildlife populations has been attributed to a number of causal agents - rapid human population growth; changes in political, institutional and socio-cultural and economic policies; change from semi-nomadic to sedentary lifestyle which has led to the expansion of permanent settlements; subdivision and sale of land in the group ranches; immigration from other parts of the country to take up agriculture, especially large scale mechanized wheat farming and intensive small-scale agriculture (Ogutu et al., 2009, Serneels and Lambin, 2001a, Homewood et al., 2001, Norton-Griffiths, 2007, Mundia and Murayama, 2009). These threats coupled with habitat alteration and increasing competition between wildlife and livestock have resulted in marked declines in wildlife numbers. However, Homewood *et al.* (2001) assert that for non-migratory wildlife species in this ecosystem, the causes of population decline are likely to be more complex and less related to the expansion of mechanized farming, which has been listed as a major cause of wildlife decline, and list droughts, poaching and loss of woody vegetation as some of the candidate driving forces behind wildlife declines.

Human activities have long raised concerns about their increased contribution to loss of native species and habitats. Wildlife tourism as a recreational activity has contributed to this loss, but little is known about its direct impacts (positive or negative) on the wildlife on which it depends (De Leeuw *et al.*, 2002). According to Karanja (2002), the immediate, long term and cumulative impacts of tourists on biodiversity are not obvious due to inherent complexities of the ecological systems they occur in. Consequently, even when an impact from tourism is quantified successfully, a further difficulty may arise in determining if that impact is biologically important in the long-term. To determine the long term impacts of tourism to wildlife species, this research examined changes in twelve species densities and distributions in the study area over a twenty year period with the corresponding increase in tourism, using count data to create kernel density maps to visualise these changes across the changing landscape. The main findings of this component of the research as shown in Chapter 5 (Figures 5.3a-5.3l) are significant and summarised as follows;

The north western section of the ecosystem displayed higher species densities than the south eastern section. The Siana and Loita sections of the ecosystem showed the greatest reduction in wildlife hotspots over the twenty year period. These changes have been demonstrated by this research as being due to a high number of tourist facilities and permanent human settlements present in Siana and increased wheat farming in the Loita plains, which have subsequently taken over historical wildlife ranges.

The gazelles (Grant's and Thompson's) and zebra did not display major changes in their spatial hotspots over the twenty years and were continuously well distributed in both the group ranches and the reserve. These species had improved grazing in the ranches as they were attracted to the short grass close to human settlements and the nutrient-rich sites of old cattle kraals. Zebra are also able to thrive on bulky and low quality forage giving them a wider range in which to feed.

Over the twenty years, Topi distribution progressively moved closer to the protected area away from the ranches and Sekenani and Talek centres with direct competition with livestock and increased disturbance from human settlements, the likely causal agents. Eland distribution progressively shifted away from the heavily human populated areas of the ecosystem towards the southern end of the reserve which has fewer tourist facilities. In 2010, the species showed a re-emergence in the group ranches, in an area with a private wildlife conservancy with controlled cattle grazing and no human settlements. Warthog and waterbuck both displayed drastic reduction in their range over the twenty years with their hotspot areas confined to the triangle section of the National Reserve. The increased tourist facilities and permanent human settlements, sources of high disturbance levels, are a likely cause for this reduction in range. Giraffe were distributed in the *Acacia* woodlands both in the protected area and ranches. However, with increased settlements and tourist facility construction in the ranches over the years, there was a reduction in available habitat and therefore range, with density hotspots confined to those areas with wildlife conservancies.

The area occupied by the twelve species in the National Reserve increased over the twenty years while the amount of land they occupied in the ranches, though still greater, showed a reduction in size, most likely a result of the conflicting land uses in the surrounding ranches. Paired samples t-tests were conducted to compare difference in area occupied by species in the Maasai Mara National Reserve and the ranches between 1990 and 2010 showed significant differences in the areas occupied by Giraffe, Grant's gazelle, Impala, Kongoni, Thompson's gazelle and Zebra which were found to occupy larger areas in the ranches. A similar t-test was used to compare changes in area occupied by all the study species in the protected area and the ranches over the same twenty year period. In 1990, a significant difference was observed with a larger area occupied in the ranches, which were then still communally owned as trust lands. Furthermore, the number of tourist facilities in the ecosystem was still relatively low numbering eleven. In 2000 and 2005, significant differences were demonstrated with larger areas occupied in the ranches, a result of droughts which had affected the country in the preceding years causing the wildlife to disperse into the ranches in search of pasture.

This research reveals that while the Maasai Mara National Reserve offered a measure of security to wildlife from conflict with local communities and competition of grazing with livestock in the ecosystem, many of the species still heavily utilised their historical dispersal areas outside the protected area, despite the demonstrated tourism related land use changes in the Mara's landscape. This observation was supported by two detailed wildlife and livestock counts carried out in 2002 and 2005, which reported that many of the Mara's wildlife species were just as abundant in the reserve as in the group ranches, the dispersal zones (Reid *et al.*, 2003, Ojwang' *et al.*, 2006). However, their populations in the ranches are under threat from habitat loss and fragmentation in these areas. It is therefore recommended that any solutions aimed at achieving sustainable conservation of Kenyan wildlife resources should be based on the premise that the majority of wildlife resides outside protected areas in community or individually owned land, and recognition given to the communities occupying these lands. Urgent implementation of the National Tourism Policy (Ministry of Tourism and Wildlife, 2006), which was developed to harmonise the existing national land-use, wildlife and tourism policies, is recommended if concerns such as loss of wildlife dispersal areas to agriculture, currently being experienced in the Mara are to be resolved and population viability of wildlife populations maintained. This is vitally important as they ultimately determine the success of the tourism industry. The current trend towards conservancy creation and the setting aside of alternative wildlife areas in the Mara Ecosystem, is a crucial first step in reducing wildlife loss and improving their habitats in the dispersal areas. However, further research into their impacts on biodiversity as well as local livelihoods is required.

7.4 Site selection for future ecotourism facilities

The inclusion of GIS techniques into wildlife management has been encouraged with predictive models seen as a way to provide visual assessments of wildlife movement patterns, habitat utilisation and interactions with surrounding environment (Obade, 2008). Used well, it can act as a powerful tool for human-wildlife conflict mitigation and land use planning. As wildlife tourism expands into new natural areas, precautionary mechanisms need to be in place to ensure that any new developments are sensitive to the fragile nature of these ecosystems by paying much greater attention to destination planning. Using GIS, necessary mechanisms can be put in place using multi-criteria decision analysis (MCDA), a decision support technique which provides a collection of procedures and algorithms necessary to design, evaluate and prioritize decisions. It allows decision makers to transform and combine geographical data to suit their preferences in order to obtain appropriate and useful information (Boroushaki and Malczewski, 2010, Arafat *et al.*, 2010) to help them determine the suitability of developments in wildlife areas.

The selection of suitable locations for a given activity is based on a set of criteria which describe the selected site's characteristics such as present land use, accessibility to transport links, water availability, geology and slopes, which may influence its suitability for a specific land use type (Kamal and Subbiah, 2007). Using a GIS and MCDA, this research generated algorithms to select, reclass, score and weight various anthropogenic and environmental characteristics of the Mara Ecosystem against stated parameters to assess its overall suitability for further tourism development (Chapter 6). Seven suitability models based on different scenarios were created and used to propose suitable locations in the ecosystem for future ecolodge and ecocamp development in line with the development requirements outlined in the 10 year Mara Management Plan. Several locations both in the protected area and group ranches were selected as likely development sites, and using two available bed-occupancy formulae (current concept of 174 acres/bed and conservancy concept of 350 acres/bed), the model calculated potential development sizes and locations.

This research demonstrated that the Mara Ecosystem can accommodate further tourism growth at low ecological cost provided it is well planned and executed. However, any developments inside the protected area are discouraged as the current visitor use pressures in the Maasai Mara National Reserve (emanating from tourists accommodated outside the reserve) are detrimental to its ecological integrity and the future of its wildlife. This research therefore recommends that any future tourist facilities be located outside the reserve in the group ranches and that ecological principles be applied when selecting locations alongside using these suitability models. The current lack of a comprehensive land use plan for the ecosystem has resulted in the conversion of previous wet-season dispersal and calving areas, for instance the Loita Plains, to land uses that are incompatible with conservation, such as large scale agriculture which reduces pasture and wildlife access and dispersal. This is especially relevant in the dry season as land gets fenced and sold as well as the development of tourism facilities which further fragments the ecosystem (Mundia and Murayama, 2009). These have consequently caused major wildlife population losses thus threatening the sustainability of tourism in the Mara.

The establishment of any new wildlife-tourism business and designation of sanctuaries in the past relied on information about how best to maximize those locations, with areas with high wildlife populations perceived as having high probability of elevated wildlife observations for tourists. This research demonstrates that any suggested management strategies aimed at minimizing ecological impacts in wildlife areas should take into account the type of tourism development, locally available wildlife species and the ecology of the site where the interactions between tourist and wildlife will take place (Newsome *et al.*, 2004) rather than looking to solely provide viewing satisfaction. The cumulative impacts of tourism, its supporting infrastructure and activities, often lead to larger and significant impact situations and it is clear from this research that the extent and significance of such cumulative impact situations depend on the sensitivity of the environment, the scale at which the sources of the impact are developed and applied as well as the effectiveness of prevailing management systems. Small scale operations in environmentally sensitive locations may therefore eventually turn into larger more destructive operations to meet the growing demands of the industry (Roe *et al.*, 1997). It is believed that the larger a natural area, the more likely it is to 'absorb' various impacts (Newsome *et al.*, 2004) as with the creation and management of wildlife conservancies where 350 acres are assigned to each bed. Care must therefore be taken, and measures put in place when setting up tourist facilities, to ensure that the carrying capacities of fragile ecosystems are not exceeded.

It has been recommended that to cater to the increasing demand for more tourist facilities in major wildlife areas such as the Maasai Mara, high use zones be developed where tourists can be concentrated in the already disturbed areas of these parks to minimise their impacts on wildlife populations (Narok County Council and Trans Mara County Council, 2008, Hidinger, 1999). However, the over utilisation of single sections of an ecosystem may lead to resource depletion and localized species loss, as evidenced by the findings of this research (Chapter 5) which indicate that all wildlife species react to human disturbance, with some e.g. eland gradually moving away from high disturbance zones. By constructing site suitability models, this research has successfully demonstrated how MCDA principles can be applied to a GIS to meet the growing demand for tourist accommodation, without compromising the ecological integrity of the wildlife areas where these facilities will be located. A GIS database of species distributions and densities, anthropogenic and natural features of the Mara Ecosystem, created during this research as well as the resulting suitability models, are to be made available to wildlife managers, policy makers and other decision makers to assist them in making decisions on any future tourism developments in this ecosystem, more so within the protected area. In addition, the suitability models created from the results of this research are easily modified and can be used under different planning scenarios in other wildlife areas in Kenya and the region. It is therefore hoped, that the results from this study will influence policy direction for tourism planning in wildlife areas for the Mara and other Ecosystems, and be used to complement the country's tourism and wildlife bills which are about to be passed into law.

7.5 Recommendations for further work

As tourism continues to gain popularity, the number of tourists to wildlife areas has increased, prompting an unprecedented rise in the development of tourist facilities to meet this demand, a situation witnessed in the Mara Ecosystem. Subsequently, there has been increased pressure on local infrastructure and services e.g. roads, water, alternative electricity supply and waste disposal systems. While the debate over tourism's impacts on wildlife and their habitats in the Mara Reserve has been on-going for more than a quarter of a century (Karanja, 2002), previous tourism research did not adequately quantify these impacts to conclusively offer conflict resolution recommendations. This research set about to address this issue by studying the relationship between wildlife based ecotourism and ungulate species in this ecosystem and focused on ways to maximize the synergy between the two while minimizing any adverse impacts to the receiving environment. The resulting site suitability models are recommended for use as tools to assist in the ecosystem's land use planning through their ability to apply suitability scores to areas selected for proposed developments.

One of this research's findings has been the recognition of local community support especially in wildlife areas, which has been acknowledged as forming an integral part of tourism's sustainable development. The inclusion of local communities in conservation activities has further been endorsed by ecotourism principles, one of which asserts that local people have the greatest repertoire of local ecological knowledge to sustainably manage the resource base (Sindiga, 1999). This aspect of ecotourism should however not overshadow any ecological impacts that it may have on surrounding ecosystems, which are the underpinning foundations of the very concept that it was developed for. In order to involve local communities who live in wildlife rangelands and encourage the sustainable growth of ecotourism, this research could be extended to further investigate the following issues which emerged during the course of the study.

7.5.1 The role of conservancies in the Mara Ecosystem

This research has reiterated finding from other studies which show that the Mara Ecosystem is currently undergoing rapid land use changes which when combined with the increasing demand for land for large scale agriculture, the increasing number of permanent human settlements and the continued habitat fragmentation, pose serious threats to the long term viability of the ecosystem's wildlife populations and challenge the sustainability of wildlife tourism. Over the last 30 years, populations of almost all large wildlife species in the Mara have fallen by more than two-thirds and are now estimated to be only one-third or less of their former levels (Ogutu *et al.*, 2011). Homewood *et al.* (2001) point out that the major changes in land cover and numbers of dominant grazer species in this ecosystem are primarily driven by private land owners responding to market opportunities for mechanized agriculture and less influenced by population growth, cattle numbers and small-holder land use. This has led to the realisation that to maintain sustainability, wildlife conservation should incorporate needs of local communities, with recommendations that incentives be used to increase economic returns from wildlife for the local people (Mundia and Murayama, 2009).

Since 2006, several conservancies, voluntary partnerships between private tourism investors and land owners in the Mara ranches, have been created to act as complimentary conservation areas to the Maasai Mara National Reserve. These agreements require land owners to voluntarily vacate their land for wildlife in exchange for regular monthly land rents. Wildlife conservancies have therefore been perceived as a novel way to promote the recovery of wildlife populations in non-protected areas (Accada and Neil, 2006, Ogutu *et al.*, 2009) thus reducing pressure in protected areas which are unable to independently sustain viable wildlife populations, minimize incidents of human wildlife conflict and absorb the growth of tourist developments. In Namibia, conservancies have facilitated increased wildlife populations and are now encouraged and their creation and function incorporated into government policies and by 2003, had 29 conservancies which covering a total area of 74,000 Km^2 of wildlife habitat. Wildlife numbers in these conservancies were shown to have increased by 70% and habitat diversity by 40% with Springbok, Oryx and Hartmann's zebra which were at historical lows in the early 1980's, showing healthy population increments (Weaver and Skyer, 2003, Norton-Griffiths, 2007). With the increase in the number of conservancies in the Mara Ecosystem (Ol Kinyei, Olare Orok, Olderikesi, Siana, Mara North, Motorogi, Naboisho and Olchoro Oiruwa Conservancies), it is expected that in future, wildlife populations will gradually increase in these areas which are located away from the Maasai Mara National Reserve, taking pressure resulting from tourism away from it. Further research is therefore needed to study the impacts these conservancies have on ungulate and other wildlife population densities and their distribution patterns, as well as study the changes in habitat quality after the exclusion of livestock from these areas.

7.5.2 Impacts of livestock integration with wildlife in conservancies

Before the change in Kenya's land tenure system, the Maasai in the Mara Ecosystem moved freely across the ecosystem with their livestock in search of pasture, limiting their interaction with wildlife. The current subdivision of land and issuing of individual land titles has meant the amount of space available for cattle has reduced, as former grazing lands are no longer communal land held in trust for the local communities. As a consequence, many Maasai take their cattle into the reserve to graze during the dry season, resulting in many cases of human-wildlife conflict. To minimize these conflicts and to increase the amount of land available for wildlife range, further work is required to fully understand the interactions between ungulates and livestock in savannah systems. Research has shown that the two groups can co-exist, with suggestions that mixed livestock-wildlife "if maintained at moderate livestock grazing levels, coupled with pastoral rangeland burning, may support higher levels of plant and animal biodiversity" than livestock-only or wildlife-only systems, as seen by the increase in plant diversity present at the edge of wildlife reserves frequented by pastoralists and their livestock"(Western and Gichohi, 1993 in (Reid et al., 2005)). It is further hypothesized that moderate or mobile livestock populations in areas of pastoral activities produce significant benefits in the form of biodiversity conservation, carbon sequestration, soil retention and fertility maintenance as well as protection of catchment areas (Reid et al., 2005).

It should be noted that although livestock directly competes with wildlife species, such as zebra and gazelles for forage in the dry season and their integration discouraged by conservationists, wildlife grazing patterns with their preference for taller grasses in the wet season benefit cattle by improving forage quality thereby highlighting the ecological process that promote coexistence among large herbivores in grasslands (du Toit, 2011). This theory has been embraced by some conservancies which are allowing controlled grazing with cattle as a mechanism to improve grass quality through intensive grazing and trampling of those areas with tall grasses, that if not grazed become overgrown, stale and unsuitable for grazers (Ol Pejeta Conservancy, 2011). It is therefore suggested that these integration techniques be further explored as a way to incorporate traditional Maasai lifestyle with wildlife conservation.

7.5.3 Inclusion of Ecological Impact Assessments in the tourism specific EIA guidelines

Environmental laws in Kenya were harmonized in 1999 and legislation passed in 2000 under the Environmental Management Coordination Act (EMCA 1999). The underlying principles of environmental assessment in Kenya are that every person is entitled to a clean and healthy environment and that all have a duty to enhance and safeguard the environment. These principles also apply to developments in tourism areas with support from the Wildlife (Conservation and Management) Act which provides licenses for access and movement of tourists through wildlife parks (Kameri-Mbote, 2000). Although sector specific EIA guidelines for the tourism industry in Kenya exist, they do not explicitly address ecological issues, a situation intensified by the lack of reliable biodiversity baseline data which makes the evaluation of tourism induced ecological changes difficult to assess.

In order to encourage environmental sustainability in Kenya, Ecotourism Kenya (EK), a civil organization with varied membership was created in 1996 to promote ecotourism and sustainable tourism practices in the country based on environmental and social criteria (Ecotourism Kenya, 2011). Like most eco-rating schemes, EK mainly concentrate on how a tourist facility manages its waste, energy and grey water systems. They however do not explore impacts that particular development has on local wildlife populations principally in terms of changes to traditional migratory paths, densities and any changes in behaviours around the facility. This research therefore recommends the addition of criteria to rate ecological impacts of any candidate facilities applying for eco-rating. These criteria can then be used to carry out ecological impact assessments on proposed locations for any new developments, and where possible, propose relevant mitigation for potential negative ecological impacts.

7.6 Conclusion

One of this research's aims was to use a GIS to project likely impact scenarios of proposed tourist developments to ungulate species in the study area. The following impacts have been noticed as possibilities following analysis carried out (Chapters 4 and 5).

1. It is highly probable that increased tourism developments in the already congested areas of the ecosystem will result in localised species losses such as eland, warthog and waterbuck, which have been observed to move away from settled areas.
2. The range of some of the larger species such as buffalo and elephant which are more vulnerable to land use intensification and have direct negative impacts on people, livestock and agriculture, is reducing and becoming more confined to the protected area. Unmanaged tourism growth coupled with loss of habitat, will eventually lead to the loss of ecologically viable populations of these species.
3. The creation of wildlife conservancies in the surrounding ranches has the potential to improve wildlife range and increase species populations as a result of the provision of conflict-free areas away from human habituation and livestock grazing.

The country's National Tourism Master Plan was formulated with a view to harmonize tourism activities through fostering its sustainable development in the country's tourism regions. It underscores the need to diversify the country's tourism product by opening new avenues such as adventure, sports and cultural pursuits thereby taking the pressure away from traditionally visited wildlife areas (Ministry of Tourism and Wildlife, 2006). This study strongly recommends the inclusion of the created suitability models into park management plans to provide development guidelines to wildlife managers and tour operators and assist in realising the objectives of the tourism master plan.

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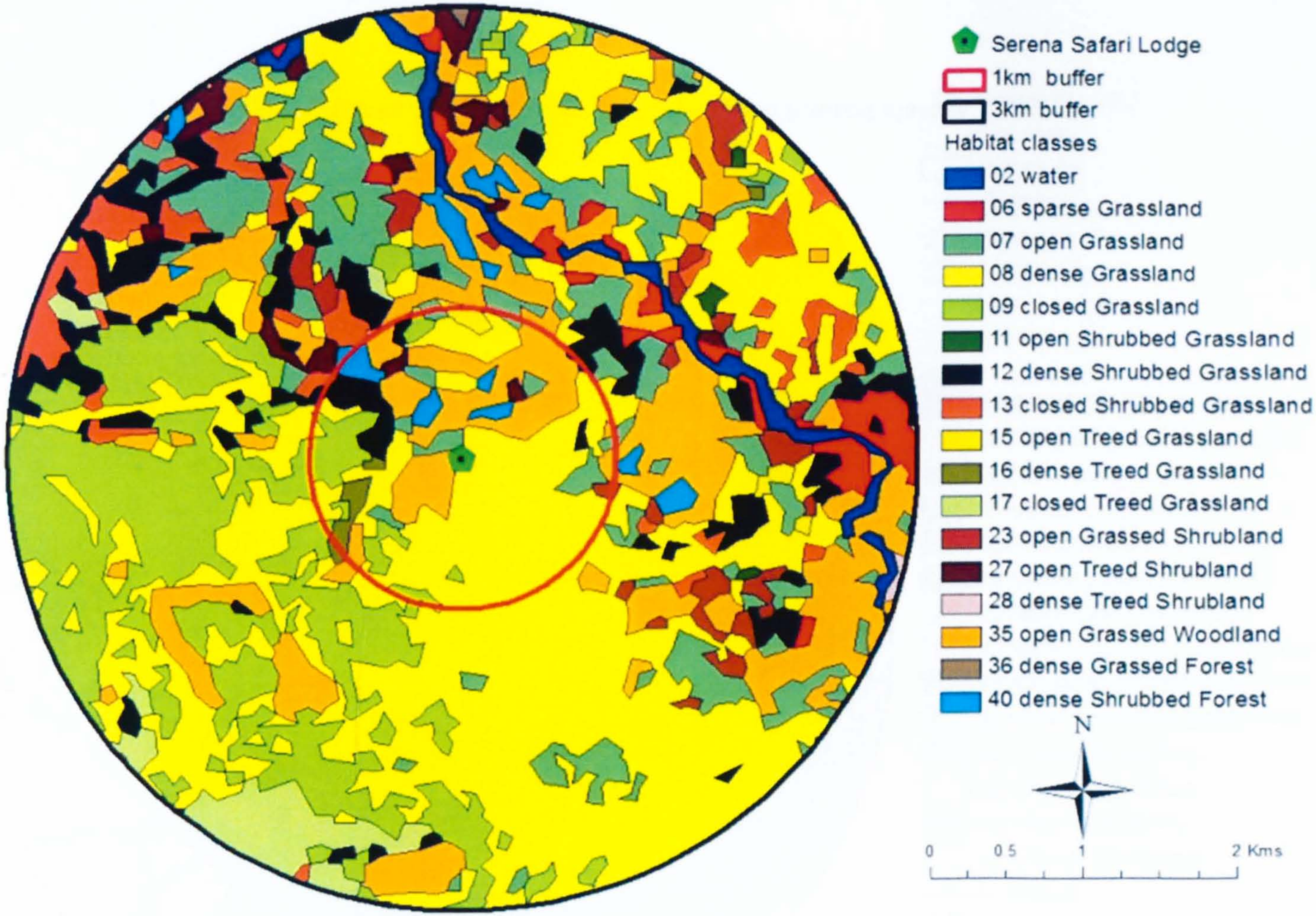
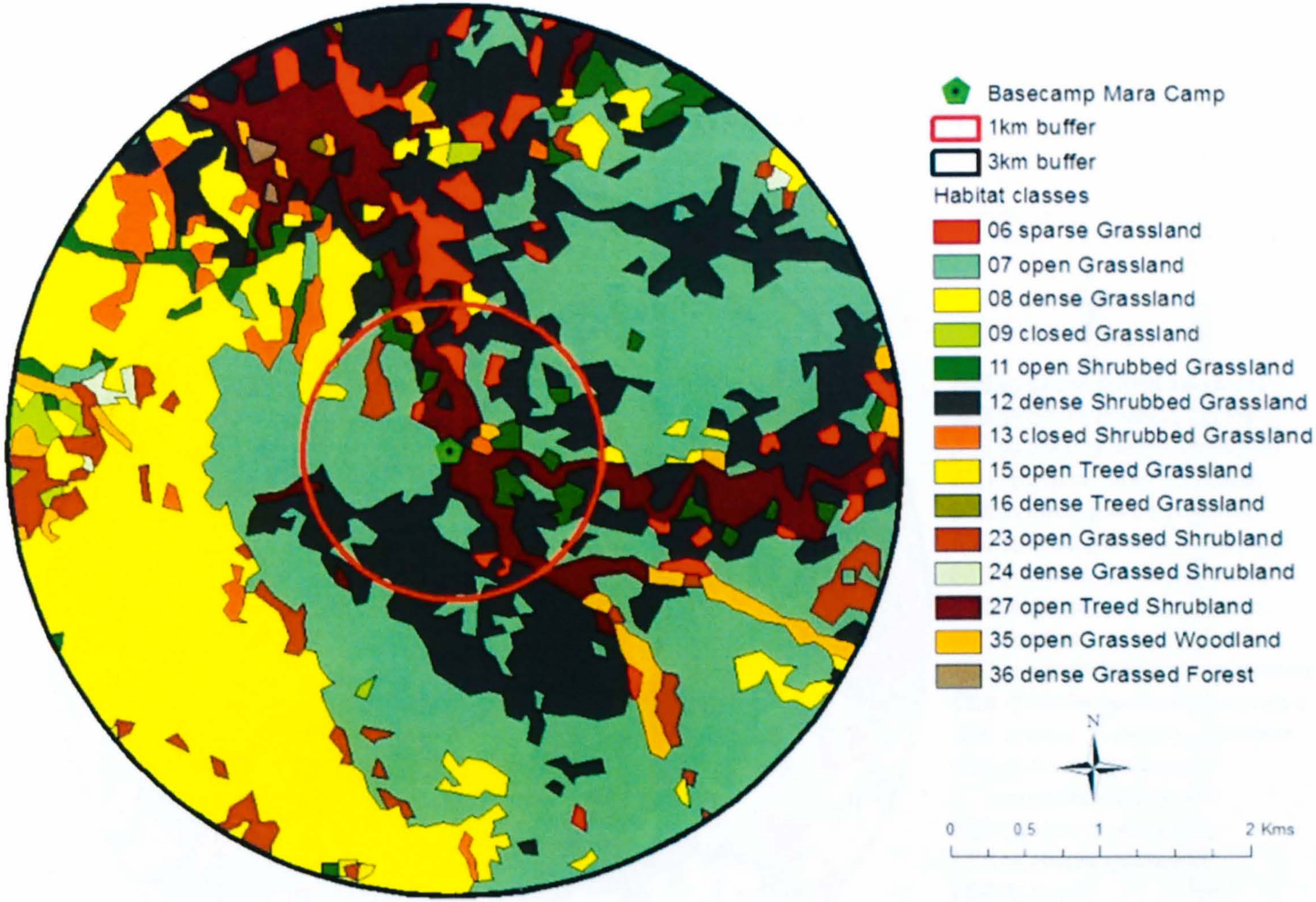
APPENDIX 1

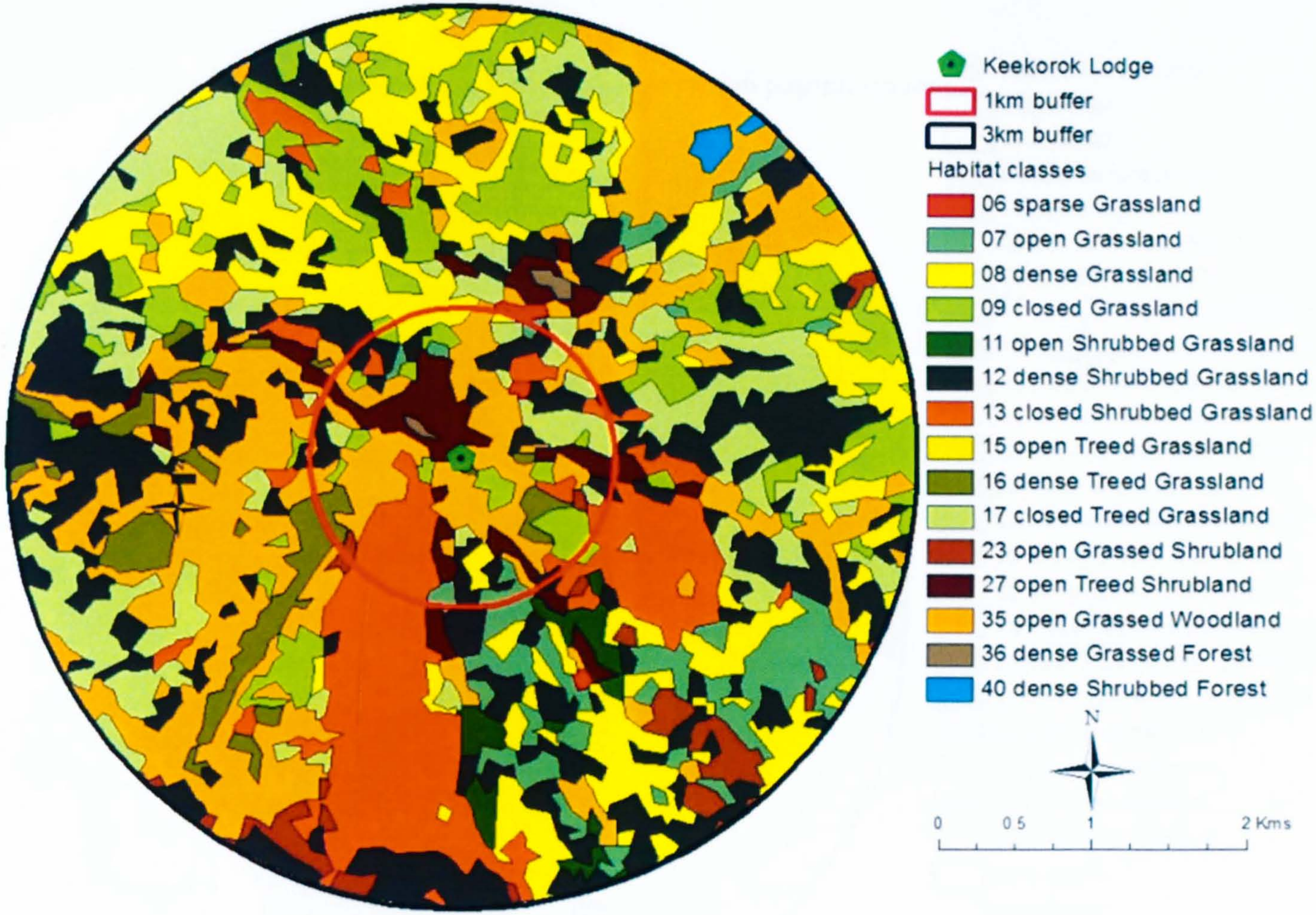
Habitat composition maps for the study sites



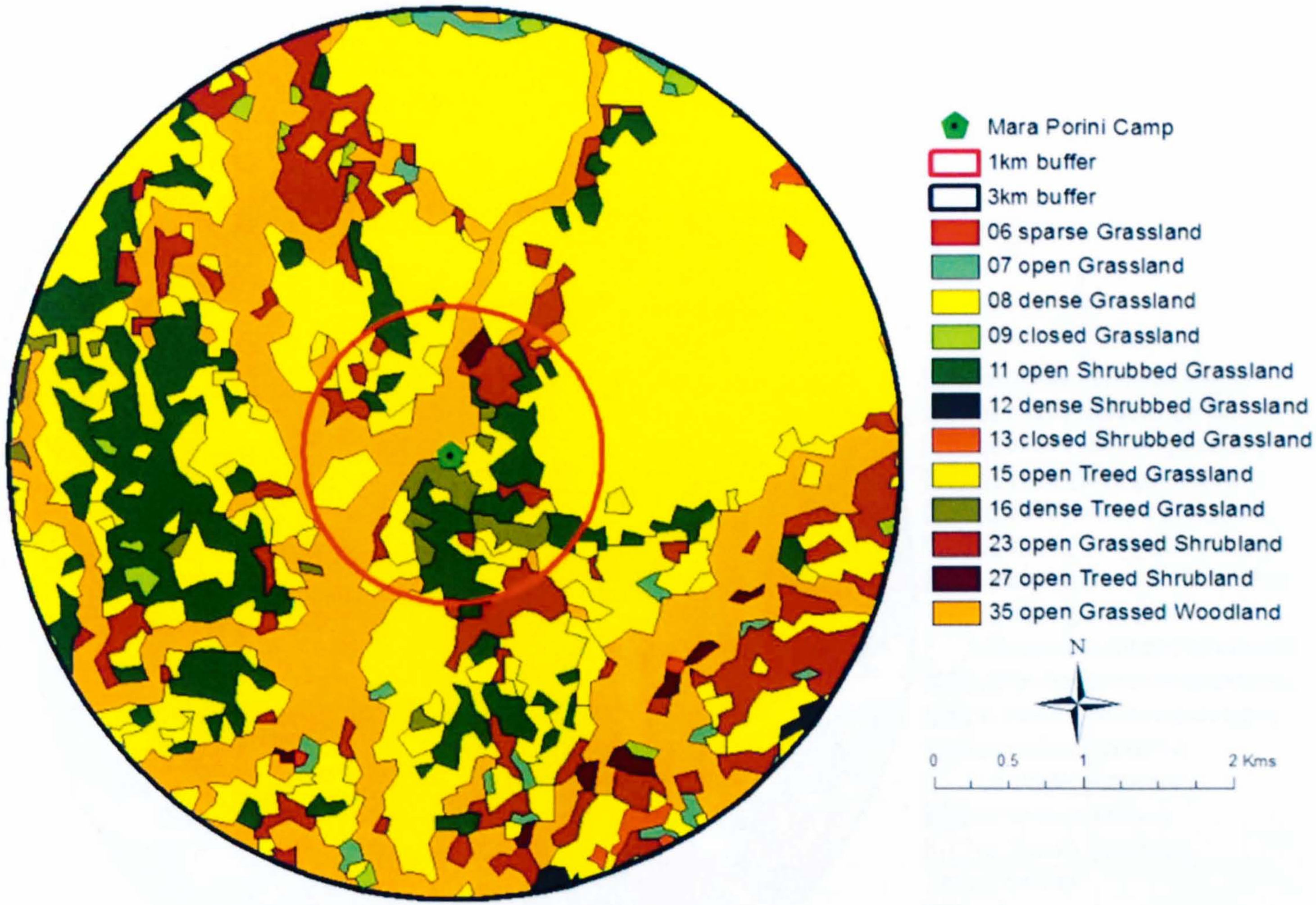
Appendix 1a: Serena Safari Lodge habitat classes



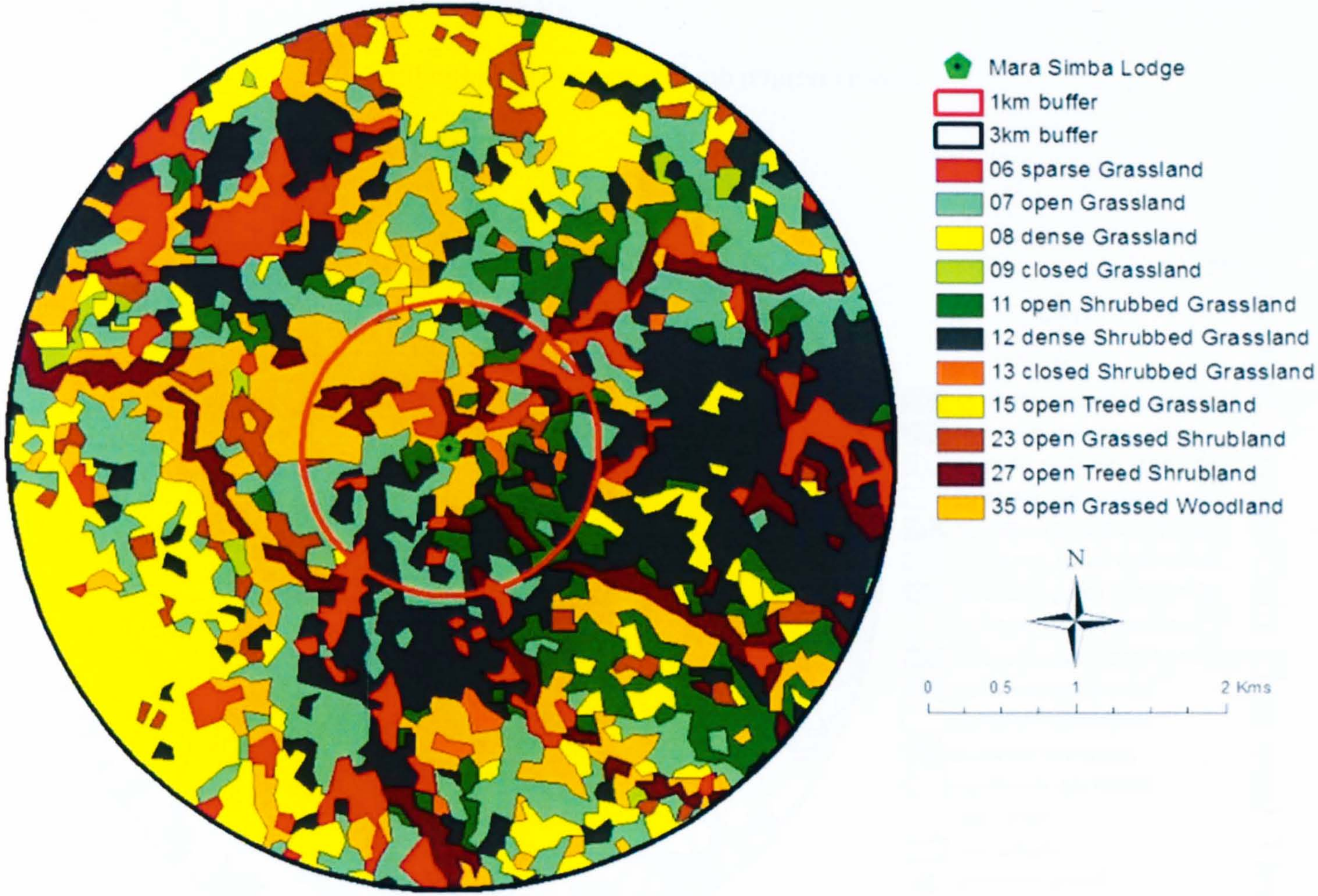
Appendix 1b: Basecamp Mara Camp habitat classes



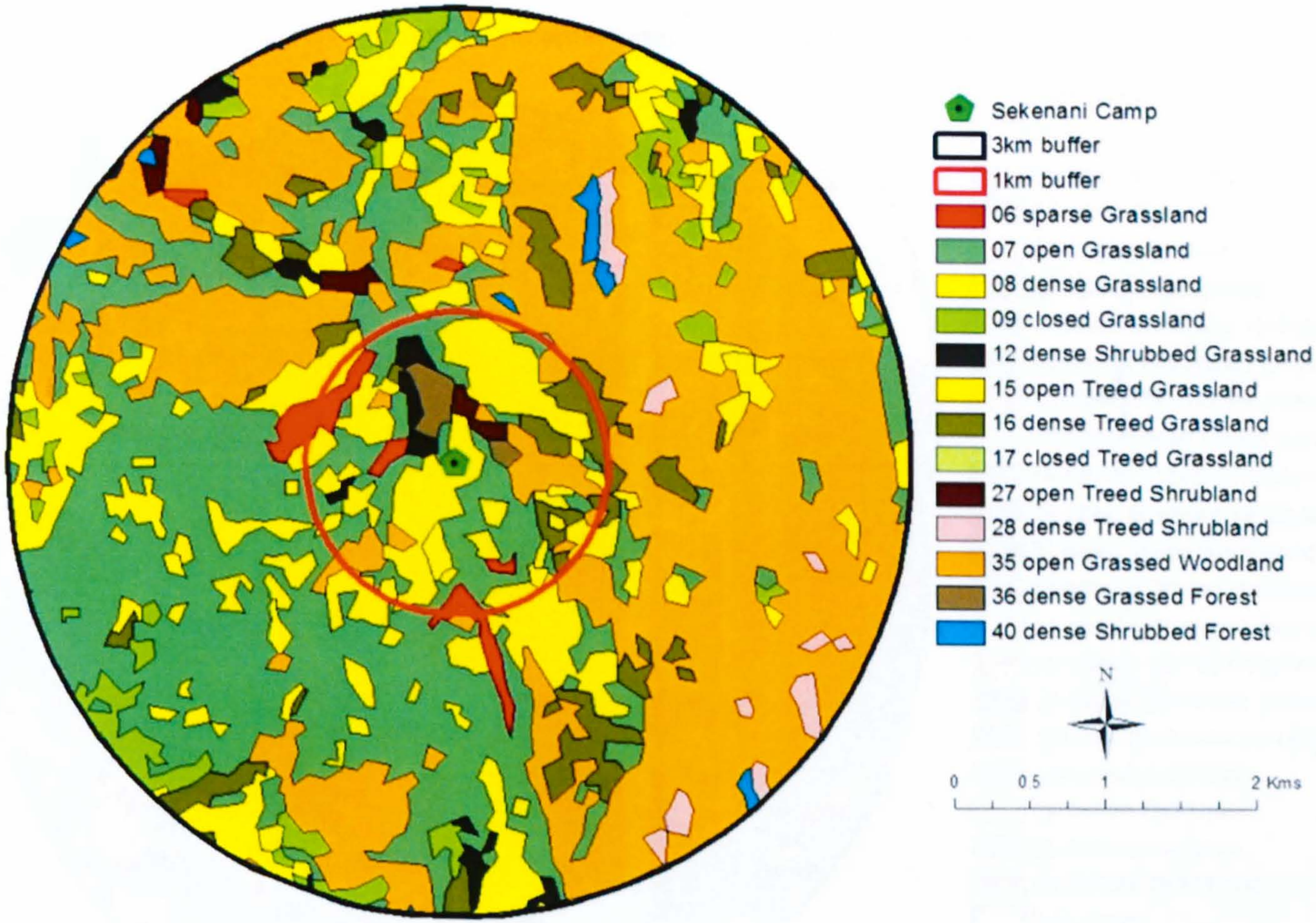
Appendix 1c: Keekorok Lodge habitat classes



Appendix 1d: Mara Porini Camp habitat classes



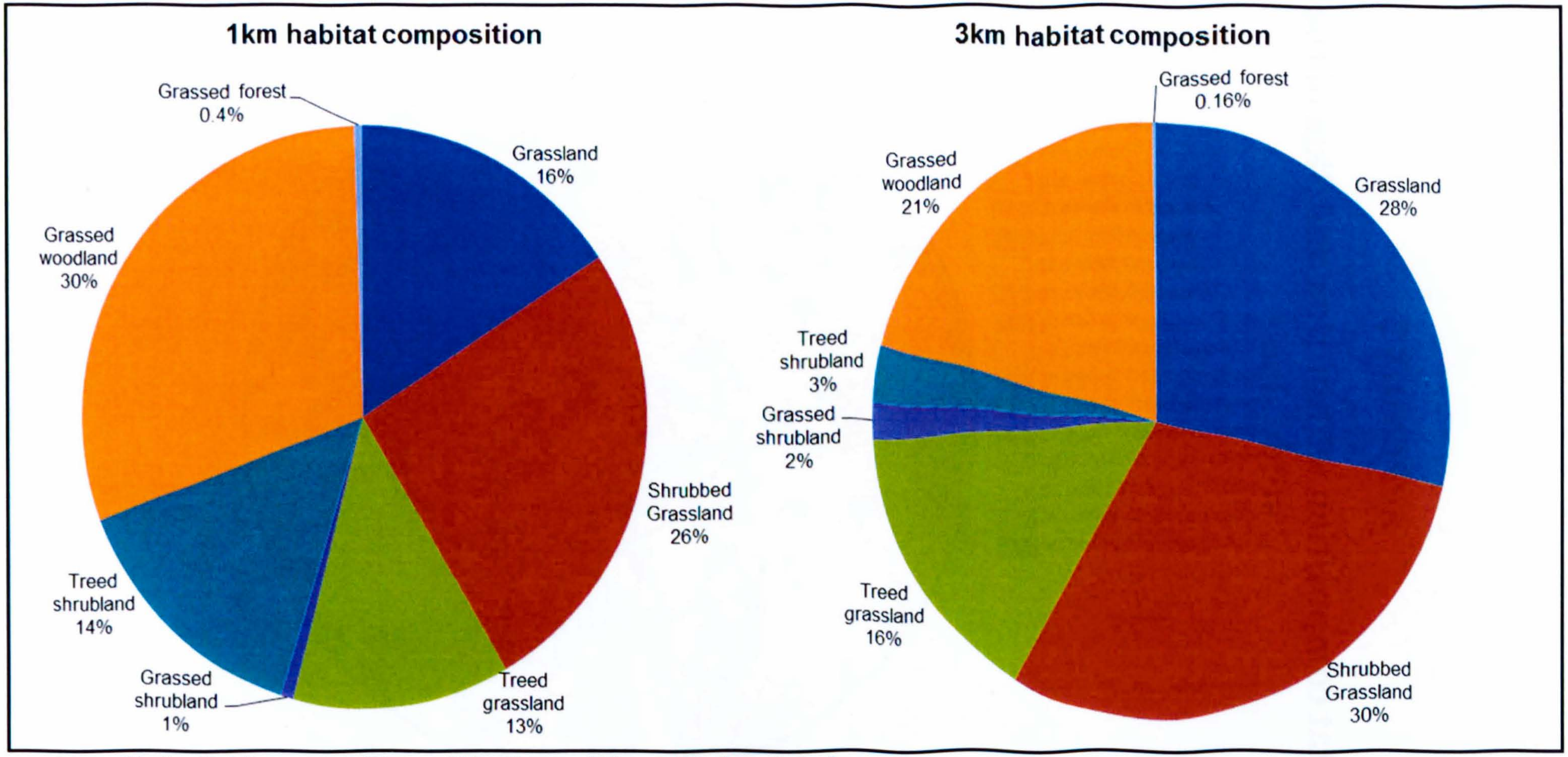
Appendix 1e: Mara Simba Lodge habitat classes



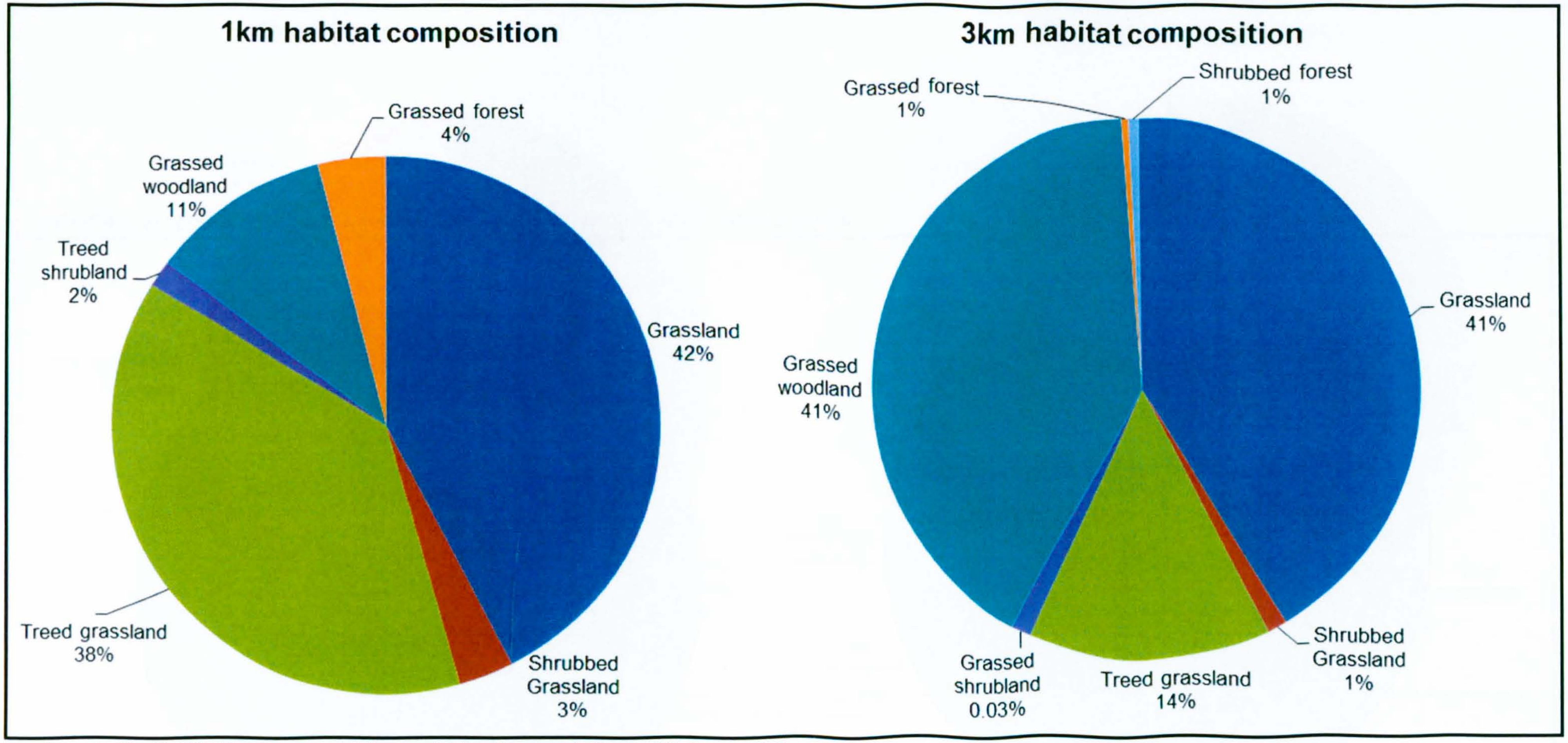
Appendix 1f: Sekenani Camp habitat classes

APPENDIX 2

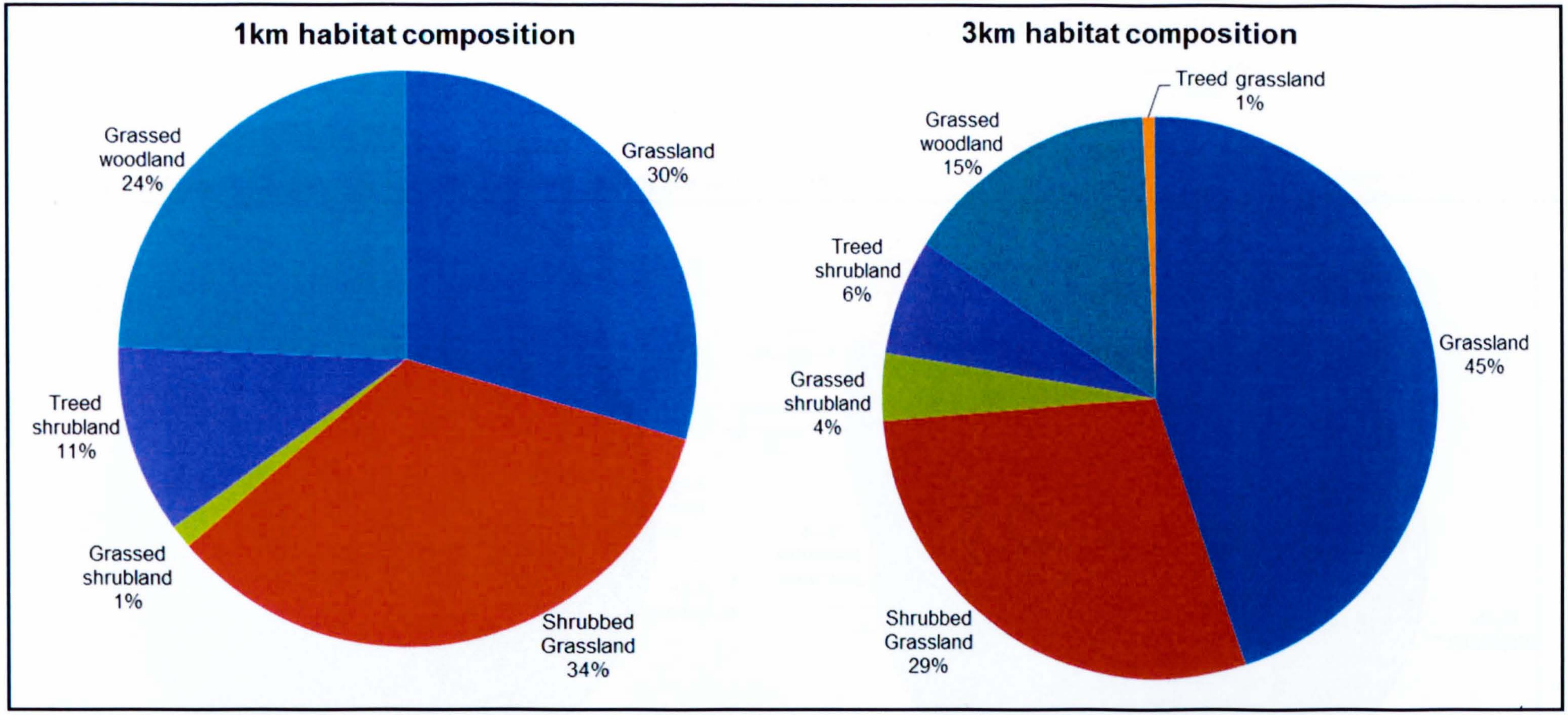
Habitat composition within 1km and 3km of the study sites



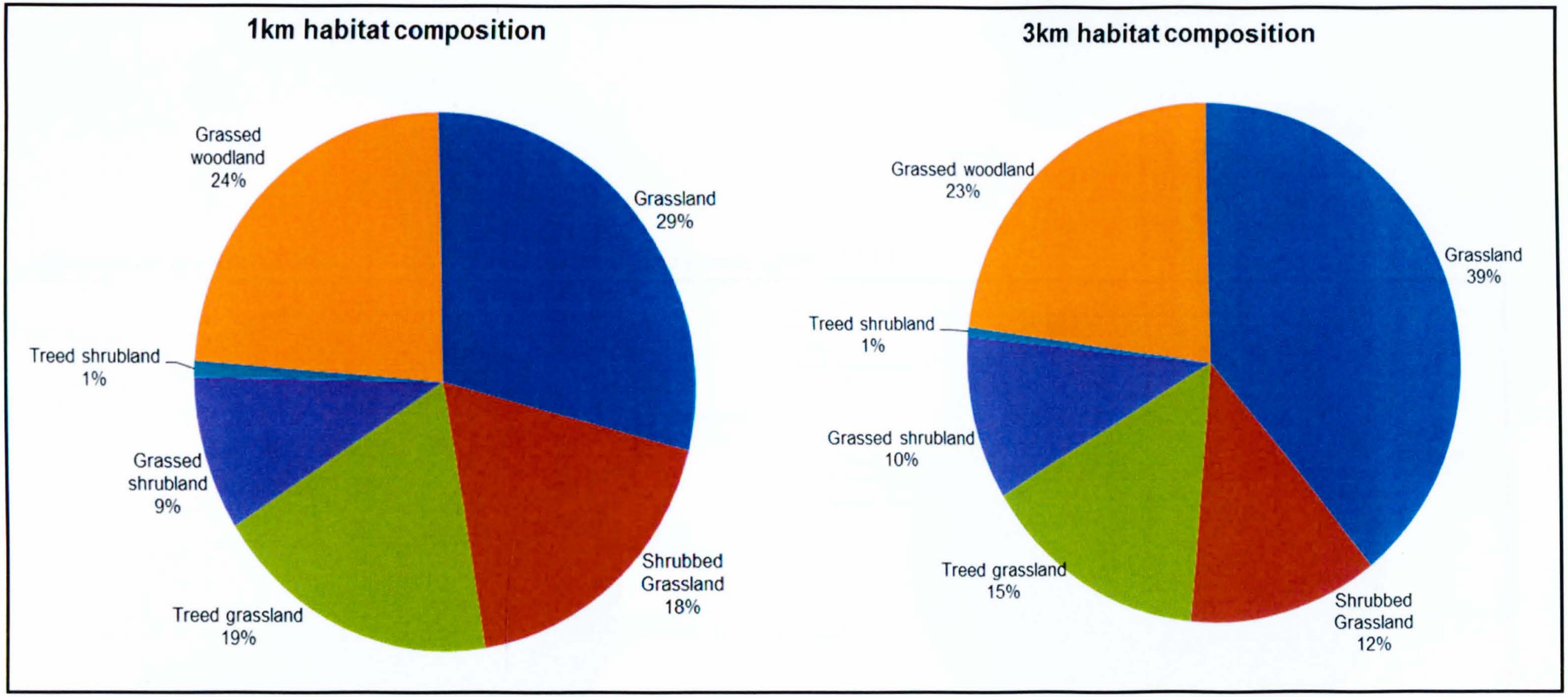
Appendix 1a: Habitat composition within 1km and 3km of Keekorok Lodge



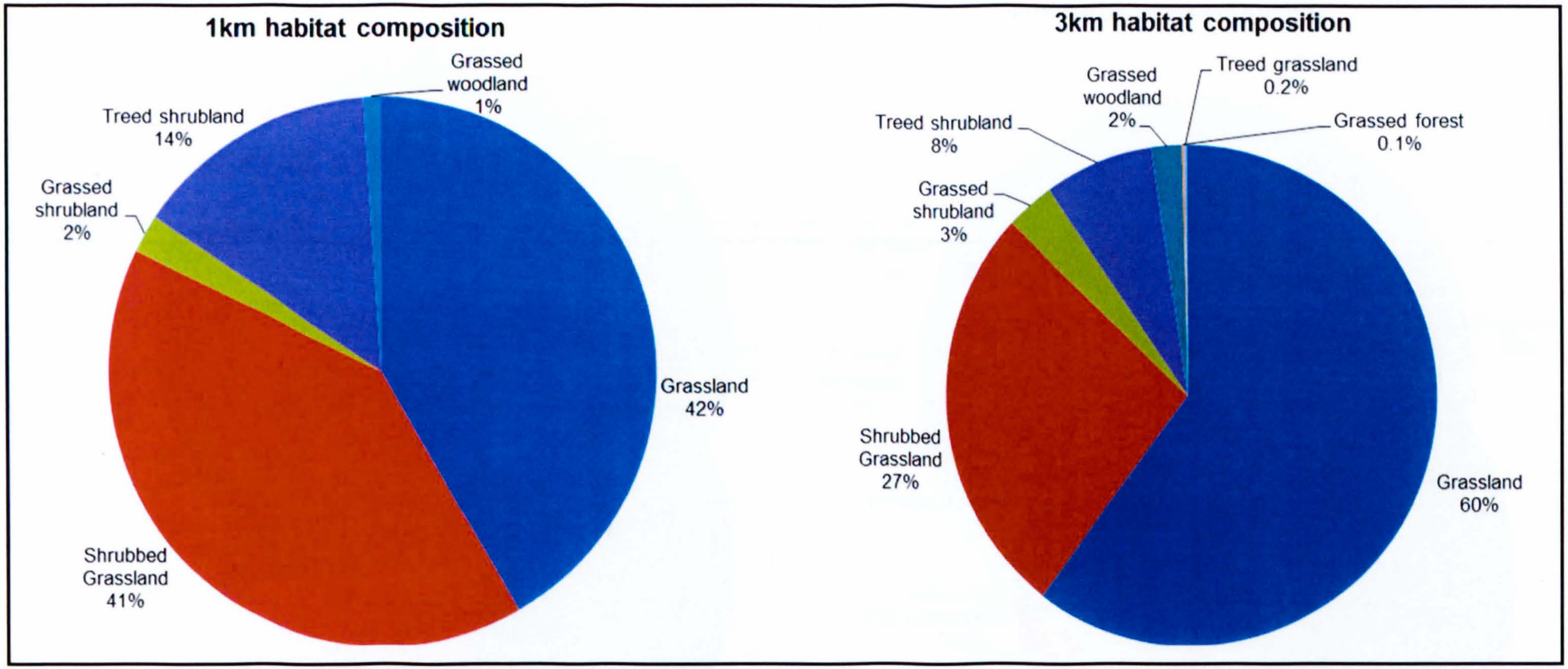
Appendix 1b: Habitat composition within 1km and 3km of Sekenani Camp



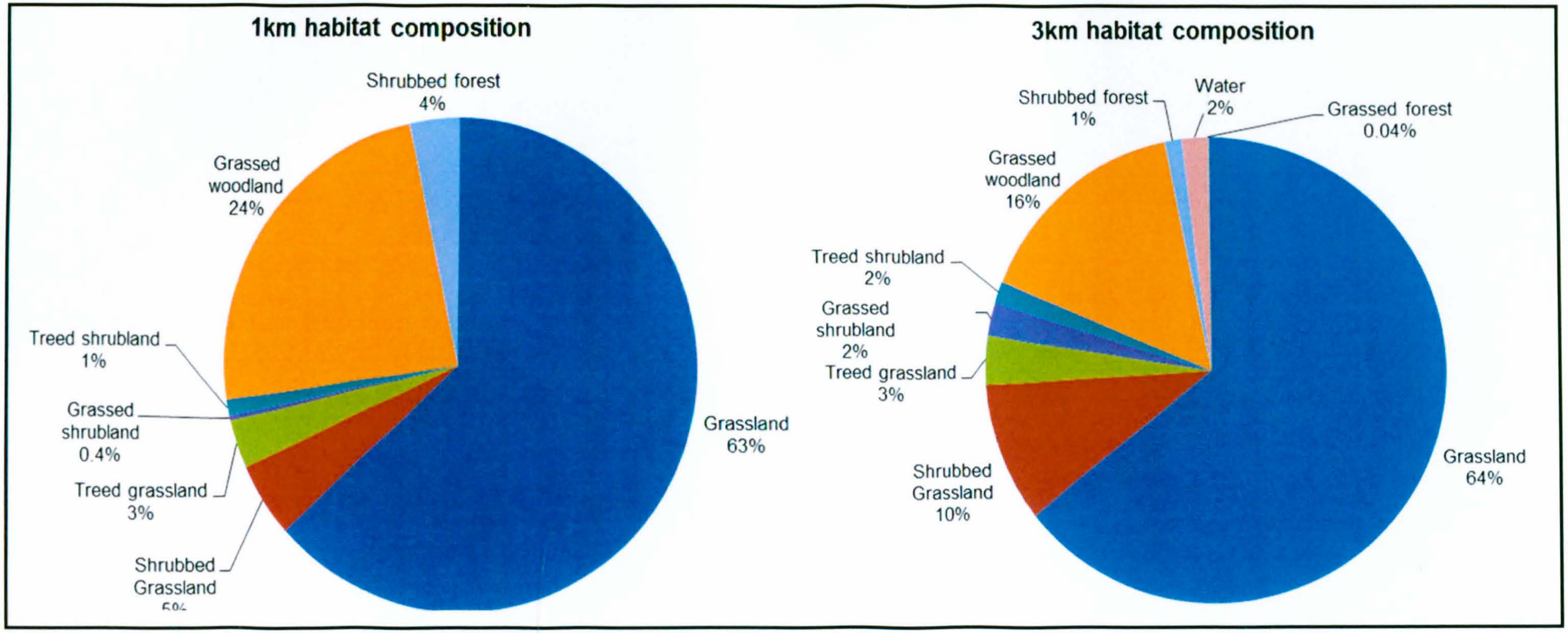
Appendix 1c: Habitat composition within 1km and 3km of Mara Simba Lodge



Appendix 1d: Habitat composition within 1km and 3km of Mara Porini Camp



Appendix 1e: Habitat composition within 1km and 3km of Basecamp Mara



Appendix 1f: Habitat composition within 1km and 3km of Mara Serena Lodge