CONSEQUENCES OF A PASTORALIST INCURSION ON LARGE MAMMAL SPACE USE IN LOISABA CONSERVANCY- NORTHERN KENYA

By

Symon Masiaine

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Fisheries and Wildlife – Master of Science

2019

ABSTRACT

CONSEQUENCES OF A PASTORALIST INCURSION ON LARGE MAMMAL SPACE USE IN LOISABA CONSERVANCY- NORTHERN KENYA

By

Symon Masiaine

Pastoralists and large mammals regularly compete over access to grazing lands. This has been true historically and is particularly relevant in the present day. In the 21st century, competition between livestock and wildlife has increased in frequency given that grazing lands are rapidly dwindling (due to habitat fragmentation and human range expansion) and drying up (via the processes of desertification fueled by climate change). These dynamics are particularly apparent in East Africa and perhaps most obvious in northern Kenya. In February of 2017, a point source pastoralist incursion occurred in Laikipia County, Kenya. An estimated 40,000 livestock grazed onto Loisaba Conservancy by armed pastoralists. The livestock resided on the 226km^2 conservancy land for four months before departing to the north. Using a broad scale camera trapping system (53 sites distributed across the conservancy), I compared patterns in site visitation rates for large mammalian herbivores that rely on grazing, browsing, and mixed feeding life histories directly before, during, and after this livestock incursion. I found stark contrasts in patterns of site visitation rates for all large herbivores across the three time periods. My results indicate that the incursion considerably changed space use of large herbivores and altered their association with a variety of landscape features, including human settlements and water access points. Competition between pastoralists and wildlife is predicted to intensify in the future, emphasizing the importance of assessing the consequences of these interactions. I discuss the implications of this competition for wildlife conservation, pastoralist livelihoods, and the role of grazing lands in modulating interactions of pastoralist livestock and large mammals.

I am dedicating this thesis to a man who has meant and continues to mean so much to me. Although you are no longer on this world, your memories continue to regulate my life. My maternal uncle Shompole Ole Larpei, though you have gone away from me, leaving a void never to be filled in my lives. Though your life was short, I will make sure your memory lives on as long as I shall live. I love you all and miss you all beyond word.

ACKNOWLEDGEMENTS

I would like to acknowledge and express deep gratitude to the people who have helped me go through this rigorous process. I would like to start by thanking my academic supervisor Dr. Robert Montgomery for his mentorship, patience, guidance, encouragement, wisdom, insights and expertise that made my endeavor possible. I cannot thank you enough, I learned so much from you. Your work is vital and meaningful in the advance of our knowledge, and in mentoring the next generations of conservationist. I am very thankful to my graduate committee members Dr. Gary Roloff and Dr. Nicholas Pilfold for their valuable input and feedback. This project would not have been possible without numerous friends and family members who helped, guided and put up with me along the way, they include Herbert Kasozi and Remington Moll for lending their analytical expertise in this study. Many thanks to my colleagues in the RECaP laboratory, A. Muneza, T. Mudumba, C. Hoffmann, S. Gray, your collective wisdom, guidance, support and inspiration helped me in countless ways, expanded my horizons and made me better every day.

Generous financial support for this research was provided by the MasterCard Foundation (MCF) Scholars Program at Michigan State University (MSU), RECaP Laboratory at MSU, San Diego Zoo Global for providing funding for my research, and basically making a lifelong dream of mine come true. I thank Dr. C. Effiong, Ms. L. Wise among others for administration of the MCF Graduate Scholars Fellowship.

I would like to thank the staff of Loisaba Conservancy, starting from the rangers’ team headed by M. Mutukei, P. Meshami S. Tokonna, Lemarleeni and finally my close friend F. Stemmo. I am most indebted to my field colleagues Lexson Larpei whose wise cultural

knowledge was able to convince the herder boys and morans not to vandalize the camera traps and his wealth of field knowledge. I am indebted to his flexibility and hard work, especially when we had to change the camera traps or install them. My gratitude goes to Mr. T. Silvester, the CEO of Loisaba Conservancy for his encouragement and motivation. I cannot forget to sincerely thank the Twiga Walinzi San Diego team headed by K. Ruppert, J. Stacy, N. Egna, Dr. M. Owen, Dr. J. Glickman, and very special thanks to D. O'Connor for all your support and trusting me that I can do this degree. Without your support, flexibility and understanding, I couldn't have pulled this off. I am particularly grateful for assistance given by M. Verch and J. Gantt, you both spent countless hours going through tons of camera traps, without your help I would still be going through the pictures.

To my friends and roommates, thank you for listening, offering me advice, and supporting me through this entire process. Special thanks to my Kenyan Lansing family group, the Maasai in Diaspora and the Kenyan Spartan groups. I would like to thank my friends in the MasterCard Foundation Scholars Programme, in particular T. Bilinto, E. Chima, R. Lesiyon, P. Koech, S. Ekene, T. Otun, K. Kaburu.

Lastly, to my family, thank you for encouraging me in all of my pursuits and inspiring me to follow my dreams. I am especially grateful to my parents, who supported me emotionally and believed in me. Finally, thanks to my love. I love you Maggy, thank you for all your support, sacrifices, patience, good humor and encouragement. I am a very lucky to have you as my wife. You are all the reason this happened. It's been a crazy few years! Thanks also to my sons Topisia and Pois and more special thank you to my daughter Naramat, you are my inspiration and source of smiles. Every time I talk to you all via WhatsApp or calls I deeply feel encouraged and rejuvenated to continue the hard graduate school life.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0. LITERATURE REVIEW

Pastoralism is a lifestyle in which people make their living by tending herds of livestock (i.e., cattle - *Bos taurus,* sheep - *Ovis aries,* goat - *Capra aegagrus hircus,* reindeer - *Rangifer tarandus,* horses - *Equus ferus caballus,* domestic yak - *Bos grunniens*, donkey - *Equus asinus,* camel - *Camelus dromedaries,* alpaca - *Vicugna pacos,* and llamas - *Lama glama*) and grazing the domestic animals on local rangelands (Blench, 2001; FAO, 2001). Livestock provide a number of quality proteins, in the form of meat, milk, and blood, to local communities (Sadler et al., 2009). These sources of nutrition are particularly important for children and lactating women (Sadler et al., 2009). Thus, condition of livestock influences human health and well-being. Though pastoralism occurs around the world, styles of livestock husbandry vary. There are two primary ways in which pastoralism has been defined. From a *productive perspective*, pastoralism can be organized to sell livestock. Here, care of livestock focuses on animal health, husbandry, and sustainable use of grazing on the rangelands (Blench, 2001). Pastoralism from a *subsistence perspective* shares many of these same values, but instead of commercialism, livestock-owners tend to live among their livestock and use them to feed their families and as an integral component to cultural practices (Blench, 2001; IFAD, 2008). Pastoralists have long overlapped and interacted with wildlife in rangelands across the world (Prins, 1992; Blench & Sommer, 1999; Butt & Turner, 2012; Homewood et al., 2012; Bedunah & Harris, 2016). The nature and strength of these interactions has reshaped the landscapes that wildlife and pastoralists share (Lankester & Davis, 2016; Butt & Turner, 2012). The spatio-temporal nature of these interactions depends on climate conditions, access to water, and the distribution and abundance of foraging resources (Prins & Voeten, 1999; Young et al., 2005; Averbeck et al., 2009; Low et al., 2009).

Interactions of pastoralists, livestock, and wildlife can be positive, negative, or indifferent. Where there is balance in the environment, livestock and wildlife can sustainably interact on rangelands. For instance, the act of livestock trampling soil can act as a tiller, stimulating growth of grass, forbs, and sedges (Maitra, 2010). Livestock also defecate and urinate on the soil which provides nutrients that promote both undergrowth and top growth of plants (Gordon, 1988; Odadi et al., 2011). Negative interactions typically occur through resource competition. Livestock compete with wildlife for forage, water, and access to rangelands. For example, grazers like African buffalo (*Syncerus caffer*) and zebras (*Equus quagga*) compete with cattle over grass which can result in overgrazing (Rowntree et al., 2004). This overgrazing subsequently affects natural composition of plant populations and their regenerative capacities (Stiling & Moon, 2005). Browsing species like giraffes (*Giraffa camelopardalis*) and eland (*Taurotragus oryx*) compete with livestock, such as camel and goats, with potentially destructive impacts on shrubs and woody plants (Goheen et al., 2010; O'Connor et al., 2016). Furthermore, species like African elephant (*Loxodonta africana*) and buffalo can be problematic to both pastoralists and their livestock as these large-bodied animals can become aggressive when competing with livestock for water and forage resources (Gadd, 2005). For example, both elephants and buffaloes have also been reported to chase, injure, and kill both livestock and herders (Gadd, 2005; Niamir-Fuller et al., 2012; Wiethoelter et al., 2015). Interactions of livestock and wildlife also facilitate disease transmission (Cleaveland et al., 2001). For instance, bovine malignant catarrhal fever, a virus that is carried mostly by sheep and wildebeest (*Connochaetes spp.*), is often highly adapted and non-lethal to the host, but can cause lethal infections when transmitted to vulnerable animals like cattle (Cleaveland et al., 2001; Catarrh, 2012). Foot-and-mouth is a disease that affects domestic cloven-hoofed animals (Jamal &

Belsham, 2013) including cattle, swine, sheep, and goats, as well as more than 70 species of wild animals such African buffalo, zebra, and warthog *(Phacochoerus africanus*; Fenner et al., 1993; Gortázar et al., 2007; Böhm et al., 2009). Diseases like these can increase the potential for negative interactions among pastoralists, livestock, and wildlife.

Excluding Antarctica, rangeland habitats occupy between 18 and 23% of global land area (Blench & Sommer, 1999; Follet & Reed, 2010). On these rangelands, pastoralism is practiced by approximately 200 million people (Blench, 2001). Many of these people maintain nomadic pastoralist lifestyles. In this case, the pastoralists move with their livestock following pasture resources in a pattern that varies from year to year (Blench, 2001). This type of nomadism is practiced in dryland and highland regions of the world, with low rainfall such as the Arabian Peninsula and Sahel of Africa (Dong, 2016). Transhumant pastoralism involves regular movement of livestock between fixed summer and winter sites so as to exploit seasonal availability of pastures annually (Dong, 2016; O'Neil, 2011; FAO, 2001). Lastly, agro-pastoralism involves supplementation of pastoralist livelihoods with small scale farming (Kerven et al., 2011; FAO, 2001). Some households grow feed crops and sell in local markets or to other households in exchange for livestock (Kerven et al., 2011).

In contrast to pastoralism, large scale livestock production is expanding across the world (Steinfeld et al., 2006; Thornton, 2010). As human populations grow globally, demand for meat and rangelands for grazing domestic animals has intensified (Herrero et al. 2010; Reid et al., 2010; Thornton, 2010). Thus, livestock-keeping is rapidly increasing, particularly in the Global South where a tripling in meat production occurred between 1980 and 2002 (World Bank, 2009; Thornton, 2010). Such growth in livestock production can negatively impact global biodiversity (Plachter & Hampicke, 2010; Schieltz & Rubenstein, 2016). These effects can be both direct and indirect. Livestock can directly affect wildlife by interfering with the quality of habitat through influencing composition, structure, and productivity of plant communities (Krausman et al., 2009). This includes conversion of landscapes for agro-pastoralism. For example, livestock, aided by human herders, typically displace and outcompete wildlife for access to grassland forage (Kauffman & Pyke 2001). Livestock can indirectly impact wildlife by changing vegetation availability and quality (Putman et al., 1989; Eccard et al., 2000). Forage intake of large mammalian herbivores may decline in nutritional value when livestock grazing reduces vegetation species diversity and causes declines in rangeland quality (Holechek et al., 1995). Livestock can also affect wildlife indirectly by contributing to climate change (Gerber et al., 2013). Methane (CH_4) production, resulting from livestock digestion, flatulence, and defecation, can contribute to climate change phenomena (Olander et al., 2013; Pérez-Barbería, 2017). Climate change is a clear threat to wildlife forage quantity and quality, water scarcity, and biodiversity (Gerber et al., 2013). Thus, there are important effects of livestock production on the environment.

1.1. Pastoralism and wildlife competition globally

The consequences of livestock grazing vary spatially according to livestock space use, niche overlap with large mammalian herbivores, and availability of habitats offering palatable primary productivity (Mishra et al., 2004; Liu et al., 2015; Kinga et al., 2018). Interactions between livestock and wildlife are examples of interspecific sympatric competition, where individuals of different species contend for the same resources in an ecosystem (Prins, 2000). These interactions often take the form of competitive exclusion, in which two interacting species are sufficiently similar in resource use patterns and one has a competitive advantage in excluding the other (Gause, 1934). Ecological consequences of this competition are informed by the theory of limiting similarity (MacArthur & Levins, 1967; Abrams, 1983), applied in the context of livestock and large mammalian herbivore interactions (Prins, 2000; Mishra et al., 2002). Owing to the importance of this theoretical principle, coexistence of livestock and wildlife is an area of scientific inquiry (see Moktan et al., 2008; Dettenmaier et al., 2017; Kinga et al., 2018). According to the projections of Food Agriculture Organization (FAO, 2009; FAO, 2011), by 2050 the global demand for livestock will increase by 70% in accordance with predicted growth in the human population (Dettenmaier et al., 2017). This suggests that pastoralism will remain a major land use in the future.

Pastoralism is rapidly changing in the 21st century as a result of natural degradation of landscapes, varying weather patterns, human population growth, and labor restrictions. Furthermore, the practice of pastoralism is becoming endangered by sedentarization and the increasing criticism of cultural practices. For example, children among many pastoralist cultures may not pursue formal education (Krätli, 2001; Ole Seno & Tome, 2013; Schmidt & Pearson, 2016). This tendency lies in stark contrast to value systems that promote youth education. Furthermore, as pastoralist lifestyles become more sedentary (Ole Seno & Tome, 2013), the structure and function of landscapes previously suited for biodiversity conservation are altered (Galvin et al., 2008; Barnosky et al., 2011). The sedentary tendencies of many pastoralists are linked to habitat change (Archer, 2010), overgrazing of rangelands (Talbot, 1986), and increasing spread of invasive shrubs on rangelands (Witt & Nongogo, 2011).

Livestock are integral to sustaining rural livelihoods in variable and heterogeneous landscapes across the globe (Ellis & Galvin, 1994; Scoones, 1994). They also provide increased economic stability to pastoralist households (Devendra & Thomas, 2002) both in small and large scale forms (Reid et al., 2001; 2004). For instance, in areas of the world cohabited by wildlife and livestock, wildlife and pastoralist cultures are important tourist attractions that can boost local economies. East Africa hosts some of the highest densities and distributions of large mammalian herbivores in the world (Sinclair & Arcese, 1995; Sinclair et al., 2008). In countries like Kenya and Tanzania, wildlife and pastoralism support tourism via wildlife viewing and cultural activities (Akama, 2002; Waithaka, 2004). However, expanding human populations, habitat fragmentation, climate change, and drought can increase conflict between wildlife and livestock. Understanding when and how competition occurs between pastoralists' livestock and wildlife can help communities, governments, and non-governmental organizations (NGOs) better realize the extent of this problem and determine how best to implement interventions.

Recent and swift changes in pastoralist grazing dynamics, especially during the dry season, has resulted in competition with wildlife for scarcer resources. These effects have been particularly apparent in northern Kenya where pastoralists use both unprotected and protected habitats to graze livestock. As a result of severe droughts and limited availability of forage on rangelands, thousands of livestock were driven to Laikipia County from the counties of Samburu, Isiolo, Baringo, Marsabit, and Turkana. In this incursion, ~40,000 livestock were grazed onto the protected area known as Loisaba Conservancy. Pastoralists and their livestock stayed for a period of three months. During that time, grazing occurred across the conservancy before herds moved to the north following local depletion of rangeland grasses. Research to understand the effects of this livestock incursion on wildlife occurrence is needed to better understand the dynamic interactions of wildlife and livestock in East African protected areas. In this thesis, I evaluated the nature of pastoralist-wildlife competition and assessed impacts of this pastoralist incursion on large mammalian spatial dynamics in Loisaba Conservancy.

2.0. INTRODUCTION

Competition between wildlife and pastoralist livestock over access to water and grazing lands is increasingly becoming a wicked problem in the 21st century (Kassahun et al., 2008; Ogutu et al., 2009; Otuoma et al., 2009; Papanastasis, 2009; Lankester & Davis, 2016). This problem lacks a clear solution given divergent values among stakeholders that differentially value wildlife conservation versus pastoralist well-being (Redpath et al., 2013; Mason et al., 2018). While competition of this type occurs worldwide, it is often most intense in the southern hemisphere (Verlinden et al., 1998; Western et al., 2009). Meat dependency has increased dramatically in the Global South, where a tripling in meat production occurred between 1980 and 2002 (World Bank, 2009; Thornton, 2010; Weiss et al., 2010; Bonny et al., 2015; Machovina et al., 2015). As livestock in the Global South are often grazed on open rangelands, rather than given provisions in confined spaces or enclosures, corresponding requirements to feed those livestock has increased the potential for resource competition with large mammalian herbivores (Rannestad et al., 2006; Odadi et al., 2007; Sitters et al., 2009). This competition has been associated with intensive overgrazing in some areas with subsequent negative consequences for livestock, wildlife, and the environment (Rowntree et al., 2004; Bilotta et al., 2007; Niamir-Fuller et al., 2012).

Overgrazing can negatively affect the natural composition of plant populations (Stiling & Moon, 2005; Walck et al., 2011) as root stocks that contain food reserves and promote regeneration in plants can be ruined (Keine, 2009). Thus, overgrazing can alter ecological succession, nutrient cycles, and landscape heterogeneity with subsequent fitness-related impacts on the wildlife that depend upon these rangelands (Kauffman & Pyke, 2001; Ceballos & Ehrlich, 2002; Balmford et al., 2003). The nature of wildlife-pastoralist interactions is further exacerbated by climate change, including extreme weather and drought (Sinclair et al., 2008). Furthermore, competition between pastoralists and wildlife for forage negatively affects livestock milk and meat production, which in turn compromises human well-being and livelihood (Randolph et al., 2007; World Bank, 2009; Kimman et al., 2013). Thus, overgrazing and pastoralist-wildlife conflict represent important environmental challenges (Bilotta et al., 2007; Niamir-Fuller et al., 2012).

East African savannas are landscapes where pastoralists, livestock, and large mammalian herbivores have interacted for thousands of years (Otuoma, 2004; Ogutu et al., 2016). These landscapes support a high diversity of large mammals, including African elephants (*Loxodonta africana*), giraffes (*Giraffa camelopardalis*), and African buffaloes (*Syncerus caffer*; Georgiadis et al., 2007; Shorrocks, 2007; Goheen et al., 2018), and are also populated with vast numbers of livestock including cattle, sheep and goats, donkeys, and camels (Nelson, 2012; Ogutu et al., 2016). Pastoralists inhabiting savanna landscapes typically provide livestock with resources by moving over large distances in search of water and grazing lands (Reid & Ellis, 1995; Butt, 2010). These movements are coordinated in accordance with seasonal shifts in forage and water availability (Niamir-Fuller, 1999; Thornton et al., 2014; Egeru, 2016). Movements and migrations of large mammals are similarly dictated by forage potential following spatio-temporal changes in resource abundance (Mose et al., 2013; Teitelbaum et al., 2015). Thus, migration facilitates large mammalian herbivores to exploit forage quality in ways that maximize intake rate over larger spatial scales (Fryxell et al., 2004; Hebblewhite et al., 2008). Consequently, there is strong potential for competition, and potentially conflict, between pastoralists and wildlife. This competition is intensified by the fact that both productive grazing lands and water availability are dynamically changing given climate change and habitat fragmentation processes (Stiling & Moon, 2005; Walck et al., 2011).

Kenya is a global hotspot for pastoralist-wildlife competition (Gadd, 2005; Tyrrell et al., 2017). There are 17 different pastoralist tribes (KNBS, 2009) that almost completely depend upon livestock for their livelihoods and well-being (Thornton et al., 2002). These include the Maasai, Samburu, Turkana, and Pokot, among others (Ameso et al., 2018; Pas, 2018). Pastoralists move their herds and flocks over extensive areas annually in search of water and productive grazing lands (Western & Finch, 1986; Leff, 2009; Lengoiboni et al., 2011). In February 2017, pastoralists from northern Kenya forcibly grazed tens of thousands of livestock onto the Loisaba Conservancy. Movement of these pastoralists, many of whom were armed with assault rifles, was motivated by severe drought in adjoining counties. This pastoralist incursion resulted in a state of insecurity characterized by banditry, cattle rustling, proliferation of illegal firearms, poaching, and property vandalism (Ngeiywa, 2008; Manasseh et al., 2012). Pastoralists grazed their livestock on conservancy lands for approximately three months before moving northward following local depletion of green grasses. This incursion, and others like it, represent a potentially major disturbance for native wildlife communities. However, the consequences of pastoral incursions on the spatial dynamics of large mammalian herbivores are presently unclear.

Here, I examined the impacts of this point source pastoralist incursion on the spatial dynamics of large mammalian herbivores in Loisaba Conservancy. Using a camera trapping network, I evaluated site visitation rates of large mammals with browsing, grazing, and mixed feeding life history strategies in the periods preceding, during, and directly after the incursion. Given rapid growth in meat dependency and ongoing climate change dynamics, there is good reason to believe that pastoralist incursions will become more common in future. Thus, documenting the impacts of livestock and pastoralist actions on large mammals will help fill important knowledge gaps yielding information that could be used to inform interventionist planning. Within this context, I discuss the implications of this study for conservation practice in savanna landscapes of East Africa.

3.0. METHODS

3.1. Study site

Loisaba conservancy (N 00 31.58.53, E 360 48.06.69, elevation range of 1,400 to 1,800 m) is a 226 km^2 protected area situated in Laikipia County, Kenya (Fig. 1). The conservancy sits within a broad matrix of other protected and community-owned lands. The northern portion of the conservancy consists of a relatively flat, open grassland with scattered shrubs and acacia bushes and trees. The Ewaso Narok and Ewaso Nyiro rivers meet at the southern and eastern edges of the conservancy (Fig. 1). The climate is semi-arid with a pronounced rainy season from April to May and lesser rainy seasons from July to August and October to November. The longer dry season is from December to March. During our study, annual rainfall at Loisaba Conservancy was 697 and 657 mm per year in 2016 and 2017, respectively.

3.1.1. Experimental design

I deployed camera traps at 53 sites across the Loisaba Conservancy between June 2016 and October 2017 (Fig. 1). I positioned each camera trap, affixed to a tree, in the centroid of a 2 km^2 resolution grid cell. I placed each camera at a height of 40–50 cm above the ground to capture large mammalian herbivores in the system. I programmed cameras to capture one photograph per trigger with re-triggers occurring every five seconds thereafter. I assessed large mammalian herbivore site visitation rates over a 15-month period. Specifically, I sampled; *i*) a 14-week period prior to the incursion (June – September 2016), *ii*) a three-week period during the incursion (March – April 2017), and *iii*) a 14-week period that began two months after conclusion of the intense incursion (July – October 2017). I note that the sampling period during the incursion was limited to three weeks because of inherent dangers of field work, widespread vandalism, and physical damage to camera traps by pastoralists and livestock herds. I collated and managed all resultant camera trap photos in digiKam, an open-source digital management application (The digiKam Developer's team, 2018) and examined all photos to identify large mammalian herbivores in the images.

3.2. Modeling framework

I used a Bayesian site visitation model (Kays et al., 2016; Moll et al., 2018) to evaluate large mammal spatial dynamics before, during, and after the incursion. Given our interest in pastoralist-livestock competition, I modeled the occurrence of wildlife species that were most likely to be directly affected by this incursion. These included browsing species, which forage on the leaves, shoots, or fruits of woody plants and shrubs; grazing species which predominantly consume grass; and mixed feeding species which forage on both grass and browse. The browsers included reticulated giraffes (*G. c. reticulata*) and eland (*Taurotragus oryx*; Codron et al., 2007). Grazers included African buffaloes, Plains zebras (*Equus quagga burchelli*), and Grevy's zebras (*Equus grevyi*; Codron et al., 2007; Hibert et al., 2010). There were two types of mixed feeders in our study area. These included African elephants (Hibert et al., 2010) and impala (*Aepyceros melampus*; Landman et al., 2018). However, given the differences between these species in body size, predator avoidance strategies, and life history (Gordon, 2003; Anderson et al., 2016; Ross, 2016; Ashiagbor & Danquah, 2017), I modeled these two mixed feeders separately.

For each large herbivore group, I modeled the number of times per week any of the species within the group visited a given camera trap (hereafter referred to as *site visitation rate*) as a function of incursion period (i.e., pre- during, and post-incursion) and spatial covariates. Site visitation rate can be interpreted as an index of the intensity of space use across the landscape (Kays et al., 2016; Moll et al., 2018). To avoid pseudo replication and help ensure temporal independence of the site visit data, I omitted site visits of the same species that occurred within 60 minutes of a previous visit by that species (Burton et al., 2015; Wang et al., 2015).

I modeled site visitation rates using a negative binomial distribution to account for overdispersion in the data (Greene, 2008). I included covariates that evaluated the effects of: *i*) incursion period, *ii*) four spatial covariates that I expected to influence large mammalian herbivore space use, and *iii*) interaction terms between incursion period and each of the four spatial covariates. I included these interaction terms to assess the possibility that relationships between large mammalian herbivores site visitation rate and spatial covariates might fundamentally shift during pastoralist incursion as wildlife sought forage and water resources while coping with this landscape-level disturbance event. The correlation coefficient between all covariates in all the seasons (preceding, during, and after incursion) was less than 0.64 indicating that the covariates that I considered were not collinear (Table 2).

3.3. Spatial covariates

I identified four spatial covariates, each expressed as rasters at a 30 m resolution across the study area, known to influence large mammal space use (Guo et al., 2017; Soofi et al., 2018; Table 1). I estimated proximity to two sources of water, human habitations, and the conservancy area boundary by calculating Euclidean distance (km) to the nearest dam, major river, human habitation, and conservancy boundary. I chose water-related covariates (i.e., distance to dams and rivers) based on the understanding that water is a basic requirement for large herbivores influencing their spatial distribution and intensity of site use (Rondinini et al., 2011). Loisaba

Conservancy owns several dams that form reservoirs for provision of water to livestock and wildlife. As human habitations are known to influence space use of large mammalian herbivores (Ogutu et al., 2017), I examined proximity to tented tourist camps, lodges, ranger posts, and the conservancy administrative headquarters. Finally, despite Loisaba Conservancy being unfenced, I calculated proximity to the boundary given that there may be important edge effects associated with large mammal occurrence in this system (Xavier et al., 2018).

3.4. Model analysis and predictions

I analyzed models in a Bayesian framework using Markov Chain Monte Carlo simulations in R (R Core Team 2017) and JAGS (Plummer, 2003) via the package *R2jags* (Su & Yajima 2012; see model code in Appendix A). For each model (i.e., one model each for grazers, browsers, and the two mixed feeding species), I ran three chains of 8,000 iterations, each following a burn-in of 2,000 iterations and thinned chains by four. I used diffuse priors for all covariates (Kéry & Royle, 2015) and checked for model convergence using R-hat statistics (values for all parameters were <1.1; Gelman & Hill, 2007). I assessed model fit using posterior predictive checks and Bayesian *p*-values by comparing a Chi-square discrepancy statistic calculated using the data with an analogous statistic calculated using data simulated from the fitted model (Kéry & Royle, 2015). Bayesian *p*-values values near 0.5 indicate an excellent fit and extreme values near one or zero indicate poor fit (Kéry & Royle, 2015). I checked for spatial autocorrelation among model residuals by plotting spline correlograms of Pearson's residuals summed across sites (Rhodes et al., 2009; Moll et al., 2018). Finally, I used the fit model to produce spatially-explicit predictive maps of large mammal space use in the pre-, during, and post-incursion periods.

4.0. RESULTS

Across the 53 sites, camera traps were active for 379 camera-trap weeks (2,653 camera-trap nights). My cameras recorded 2,200 site visits of the focal large herbivore species. Impala were most commonly-detected (*n* = 751 site visits) while African buffalo were least-commonly detected (*n* = 43 site visits). Bayesian *p*-values indicated good to excellent fit for all models ($p_{\text{grazers}} = 0.60$, $p_{\text{browsers}} = 0.64$, $p_{impala} = 0.63$, $p_{elephant} = 0.56$). Spine correlograms indicated lack of spatial autocorrelation among the residuals in all models (Appendix A).

4.1. Spatial dynamics

4.1.1. Browsers

Distance to dam had little effect on the site visitation rates of the browsing large mammalian herbivores in the pre-, during, and post-incursion periods (Fig. 2a; Table 2). Site visitation rates of browsers demonstrated completely opposing patterns in the pre-incursion period when compared to during the incursion (Fig. 3a; Table 2). Site visitation rates increased closer to the boundary in the pre-incursion period (Fig. 3a). I detected a comparable effect in the post-incursion period (Fig. 3a; Table 2). Distance to human habitation had little effect on browser site visitation rate in the pre- and during incursion periods, but the pattern was pronounced in the post-incursion period when site visitation rate was considerably higher closer to human habitation (Fig. 4a; Table 2). Browsers preceding, during, and after the incursion showed little relationship with distance to the river (Fig. 5a; Table 2). The spatial maps demonstrate that browsers used the eastern edge of the conservancy in the pre-incursion period, the central portion of the conservancy during the incursion, and the center, north, and east of the conservancy in the post-incursion period (Fig. 6a).

4.1.2. Grazers

Patterns of site visitation rates in relation to distance to dam were non influential in pre-incursion period and completely opposing when compared between the during and post-incursions periods (Fig. 2b; Table 2). During the incursion grazers visited sites closer to dam and after incursion they visited sites father from the dam (Fig. 2b; Table 2). Across all three time periods, grazers tended to visit sites closer to the boundary of the conservancy (Fig.3b; Table 2). Grazer site visitation rates in relation to distance to human habitation changed considerably across the three time periods (Fig 4b; Table 2). For instance, grazer site visitation rates were considerably higher in sites near to human habitation in the post-incursion period (Fig. 5b; Table 2). Finally, grazers visited sites nearer to the rivers in the pre-incursion period and this pattern was completely opposite in the post-incursion period (Fig. 5b; Table 2). Grazers used the eastern portion of the conservancy in the pre-incursion period, their use was dispersed in the during incursion period, and they used the center, north, and east of the conservancy in the post-incursion period (Fig. 6b).

4.1.3. Mixed feeders

Distance to dam was an influential covariate for elephant site visitation rate in the pre-incursion period, but not so in the during and post-incursion periods (Fig. 2c; Table 2). Elephant site visitation rate increased nearer to dams in the pre-incursion period (Fig. 2c). This same pattern was evidential in relation to the distance to the boundary of the conservancy (Fig. 3c; Table 2). In the pre-incursion period, elephant site visitation rate was higher farther from human habitations, but there was relatively no effect of this covariate in the during and post-incursions periods (Fig. 4c; Table 2). Elephant site visitation rate was higher nearer to rivers across all three time periods, though this effect was diminished in both the during and post-incursion periods

(Fig. 5c; Table 2). Elephants widely used the conservancy in the pre-incursion period with very low site visitation rates in the during and post-incursion periods (Fig. 6c).

Distance to dam had a negligible effect on impala in the pre- and during incursion periods, though impala site visitation rate increased farther from the dams in the post-incursion period (Fig. 2d; Table 2). Impala site visitation rate was highly variable between the three time periods for the distance to boundary, distance to human habitation, and distance to river covariates (Fig. 3d; Fig. 4d; Table 2). Impala used the eastern edge of the conservancy in the pre-incursion period, the central portion of the conservancy during the incursion, and the center, north, and east of the conservancy in the post-incursion period (Fig. 6d).

5.0. DISCUSSION

My research sought to quantify the effects of a pastoralist incursion on the spatial dynamics of large mammals. The results indicated that large mammals were highly affected, but that the magnitude and extent of these effects differed depending on the large mammalian herbivore group. Before the incursion, large mammalian herbivores from all functional groups tended to avoid human habitations and used habitat closer to the river and the conservancy boundary. During the incursion, all functional groups were closer to human habitation and farther from rivers and dams. After the incursion, the functional groups of browsers, grazers and mixed feeders (impala) were closer to the conservancy boundary and river. These results highlight complex and often strong effects of a pastoralist incursion on the spatial dynamics of large mammalian herbivores. The underlying mechanisms associated with these patterns suggest that the livestock in this pastoralist incursion were able to competitively exclude large mammalian herbivores, or that large mammalian herbivores avoided pastoralists and their livestock as forms of disturbance. However, I acknowledge that water is also an important variable given that the incursion itself was motivated by widespread drought in the region. Thus, the results of my study productively advance discourse on spatial dynamics of large mammalian herbivores in relation to a pastoralist incursion.

Water is an essential resource in the savannas of East Africa and a fundamental component of seasonally dynamic movement and land use among large mammals (Coppock et al., 1986; Fryxell et al., 2004; Hopcraft, 2010). The Ewaso Narok and Ewaso Nyiro rivers provide the only permanent sources of water in Loisaba Conservancy as well as the human communities that lie downstream. Thus, rivers act as a vital lifeline for wildlife, local people, and their livestock (Didier et al., 2011; Ontita, 2012). During the incursion, the Ewaso Nyiro river dried up and there was no water for both wildlife and livestock. This is likely yet another reason why we detected all large herbivore groups to move away from the river and concentrate on the central part of the conservancy during the incursion. The central part of the conservancy features dams where water was reliably located (Fig. 5a, b, c, d). The conclusion is that incursions such as the one documented here can dramatically alter animal-habitat associations to both natural and anthropogenic features.

Additionally, the incursion also was associated with declining forage availability. The livestock grazed onto the conservancy locally depleted the grass resources. During this study, I observed scores of large mammalian herbivores that died as a result of these conditions. Changes in availability and accessibility of forage was important to all large mammal herbivores and livestock, but manifested in different ways. Browsers, for instance, redistributed themselves across the conservancy probably in search of potential forage to maximize their nutritional requirements (Owen & Smith, 1982; Kinga et al., 2018). Wild grazers (buffalo and zebras) and cattle both depend on grass for their nutrition requirements (McNaughton & Georgiadis, 1986;

Beekman & Prins, 1989; Sitters et al., 2009). This can lead to competition and facilitation of grazers and livestock and was likely a mechanism associated with the pattern of grazers dispersing widely across the conservancy during the pastoralist incursion (Young et al., 2005; Odadi et al., 2011; Fig. 6b). I also found impala, as a mixed feeding species, to overlap with grazers along riverine areas and conservancy boundaries preceding the incursion (Fig.6d, b). During the incursion, they moved to the central part of the conservancy and overlapped with browsers in habitat that was closer to human habitation (Fig. 6c, a). After the incursion period, impalas visited sites closer to the river and conservancy boundary increased and was once again overlapping with grazers (Fritz et al., 1996; Hibert et al., 2010). I suspect that these patterns, in part, derive from impalas' dynamic feeding style allowing them to adjust their spatial interactions with livestock, browsers, and grazers (Hibert et al., 2010).

My research provides additional evidence for the position that pastoralism can have pronounced effects on large mammalian herbivores (Hempson et al., 2017). Ultimately, the nature and intensity of these effects will vary according to numerous factors, including the life history characteristics of the large mammals, seasonality, climate, the number of livestock, and the style of livestock husbandry (Kinga et al., 2018). I acknowledge that assessments across a three-month period directly before and after a large livestock incursion are likely not long enough to fully comprehend the impacts of pastoralist-wildlife conflict. I suspect that different species might have varying periods of recovery to normal dynamics following such incursions. Nonetheless, my study illuminates the highly disruptive potential of pastoralist incursions on the spatial dynamics of large mammalian herbivores.

5.1. Implications for conservation

Although East Africa still supports some of the largest populations of large mammalian herbivores on earth (Ogutu et al., 2016), my analysis shows that spatial dynamics of these species in northern Kenya can be compromised by unmanaged pastoralist incursions. In northern Kenya, pastoral land continues to shrink. Land conversion into farming, human population growth, and the sedentarization of pastoralists have adversely affected grazing resources with coupled negative impacts on both wildlife and livestock.

My research describes the short-term effects of pastoralist incursions on the spatial dynamics of large mammal herbivores. Research of this type is needed for the creation of progressive policies and management decisions regarding pastoralist communities living adjacent to conservancies, as well as pastoralists who originate from other counties and move their livestock over broad spatial scales. This research also has potential applications in catalyzing new dialogues relating to the ways in which pastoralist perspectives can be actively involved in conservation practice. Overall, my research is needed to preserve pastoralist well-being while conserving important species of wildlife that share landscapes with livestock.

APPENDIX

Table 1. Description of covariates used in the site visitation models for large mammalian herbivores in relation to a pastoralist incursion in Loisaba Conservancy, Kenya, May 2016 – October 2017.

Covariate	Description
Distance to dam	Euclidean distance (m) of camera trap site to dam, There are a number of dams in the Conservancy that supply wildlife with water.
Distance to boundary	Euclidean distance (m) of camera trap site to boundary of the Conservancy.
Distance to human habitation	Euclidean distance (m) of camera trap site to closest human habitation. There are several areas of human habitation and use in the Conservancy including tented tourist camps, Loisaba star beds, Acacia campsite, an airstrip, ranger posts, and the Conservancy administration headquarters
Distance to river	Euclidean distance (m) of camera trap site to the main river, the Ewaso Nyiro. The river runs from the south western boundary to the mid-eastern boundary of the Conservancy (see Fig. 1)

Table 2. Posterior means and 95% credible intervals for parameters from site visitation models for the three large mammal herbivore groups browsers, grazers, and mixed feeders (elephant and impala) fit to data across 53 sites in Loisaba Conservancy, Kenya deployed between May 2016 and October 2017. See Table 1 for descriptions of the covariates.

	Browsers			Grazers			Elephant			Impala		
variable	mean	low	up	mean	low	up	mean	low	up	mean	low	up
Intercept*	-0.9	-1.28	-0.54	-0.18	-0.49	0.13	0.17	-0.09	0.42	-0.71	-1.07	-0.35
period_incursion	-0.27	-1.36	0.7	0.9	0.24	1.64	-4.46	-7.34	-2.36	0.66	-0.15	1.44
period_post_incursion	-0.2	-0.77	0.35	0.44	0.01	0.87	-1.72	-2.27	-1.19	1.09	0.64	1.55
Distance to dam_pre	0.04	-0.41	0.51	-0.07	-0.47	0.32	-1.11	-1.47	-0.75	-0.1	-0.58	0.42
Distance to dam_during	-0.51	-1.57	0.51	-0.18	-1.17	0.79	0.48	-1.83	2.64	0	-0.96	0.94
Distance to dam_post	0.46	-0.36	1.23	0.52	-0.08	1.11	0.41	-0.32	1.12	0.97	0.23	1.72
Distance to boundary_pre	-1.38	-1.85	-0.94	-1.28	-1.66	-0.92	-0.41	-0.7	-0.11	-0.63	-1.06	-0.2
Distance to boundary_during	2.63	1.53	3.86	1.1	0.11	2.02	1.32	-0.53	3.49	1.45	0.48	2.45
Distance to boundary_post	0.22	-0.61	1.05	0.5	-0.09	1.05	0.54	-0.11	1.24	-0.68	-1.36	-0.06
Distance to human_pre	-0.48	-1.01	0.05	0.13	-0.38	0.63	0.8	0.41	1.21	0.18	-0.39	0.69
Distance to human_during	1.18	-0.21	2.63	-0.04	-1.03	1.01	-0.71	-3.91	2.44	0.44	-0.63	1.56
Distance to human_post	-1.31	-2.36	-0.25	-1.31	-2.04	-0.57	-0.42	-1.28	0.51	-2.4	-3.3	-1.53
Distance to river_pre	-0.33	-0.66	0	-0.8	-1.08	-0.54	-0.69	-0.93	-0.45	-1.44	-1.85	-1.04
Distance to river_during	0.46	-0.79	1.77	0.77	-0.24	1.71	-2.01	-4.92	0.16	1.66	0.7	2.62
Distance to river_post	0.5	-0.08	1.07	1.52	1.05	2	0.19	-0.46	0.8	2.1	1.55	2.68

*The intercept represents the natural log of mean site visitation rate during the pre-incursion period. Thus, parameters for period effects (rows two and three) are relative to the pre-incursion

LIST OF FIGURES

Figure. A1. The 226 km^2 Loisaba Conservancy situated in Laikipia County, Kenya. Triangles indicate Human habitations, the blues V shaped images are Loisaba dams and blue lines indicate the Ewaso Nyiro and Narok rivers, the red stars show the distribution of camera traps. The two rivers meet at the Southeastern corner of Loisaba and form one Ewaso Nyiro river.

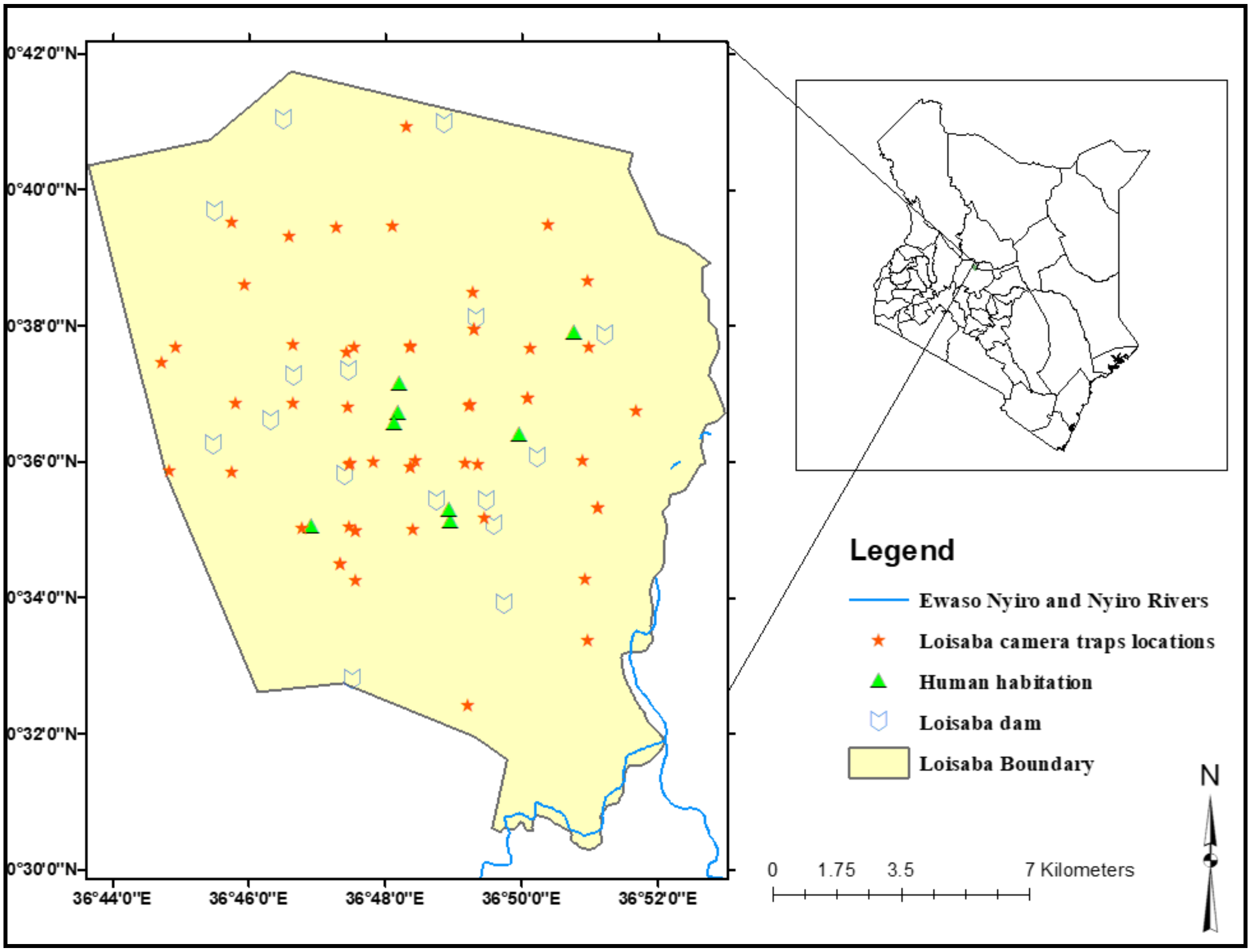


Figure. A2. Plots of effects of distance to dam on site visitation rates for a) browsers, b) grazers, c) mixed feeder – elephants, and d) mixed feeder - impala from the site visitation model fit to data across 53 sites in Loisaba Conservancy, Kenya, between May 2016 and October 2017. The gray lines represent predictions from a random posterior sample of 200 iterations to depict uncertainty**.**

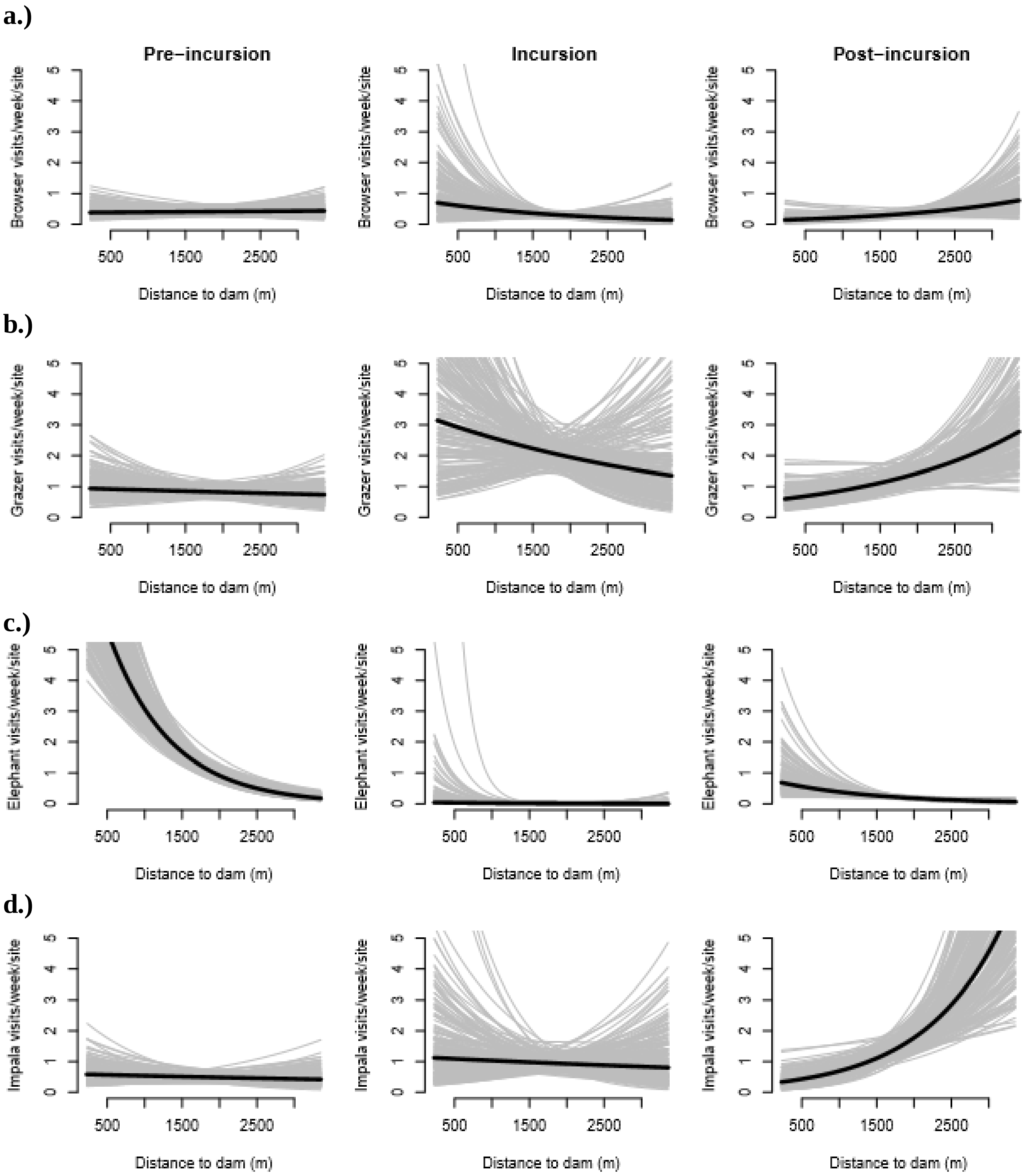


Figure. A3. Plots of effects of distance to boundary on site visitation rates for a) browsers, b) grazers, c) mixed feeder – elephants, and d) mixed feeder - impala from the site visitation model fit to data across 53 sites in Loisaba Conservancy, Kenya, between May 2016 and October 2017. The gray lines represent predictions from a random posterior sample of 200 iterations to depict uncertainty**.**

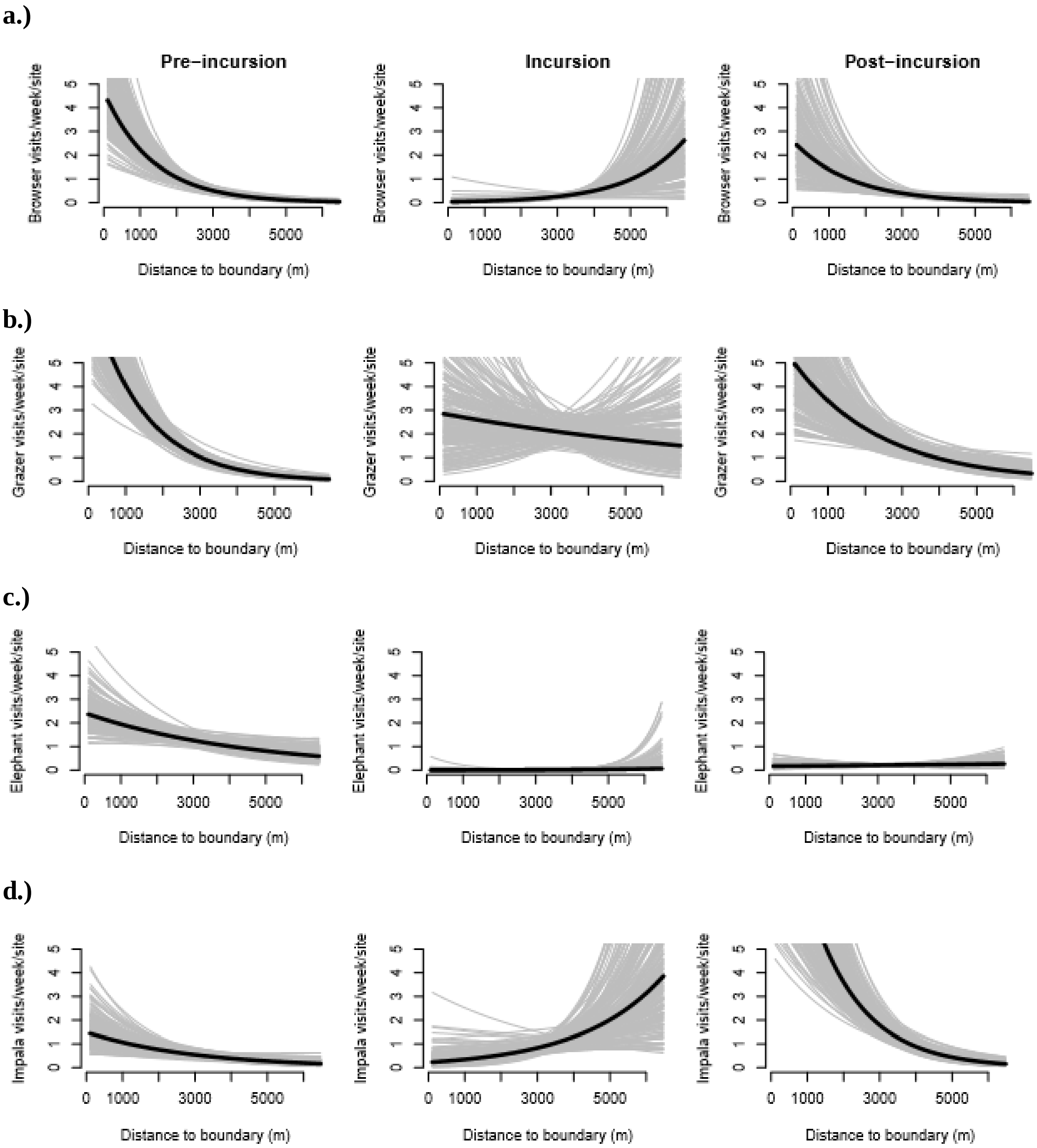


Figure. A4. Plots effects of distance to human habitation on site visitation rates for a) browsers, b) grazers, c) mixed feeder – elephants, and d) mixed feeder - impala from the site visitation model fit to data across 53 sites in Loisaba Conservancy, Kenya, between May 2016 and October 2017. The gray lines represent predictions from a random posterior sample of 200 iterations to depict uncertainty

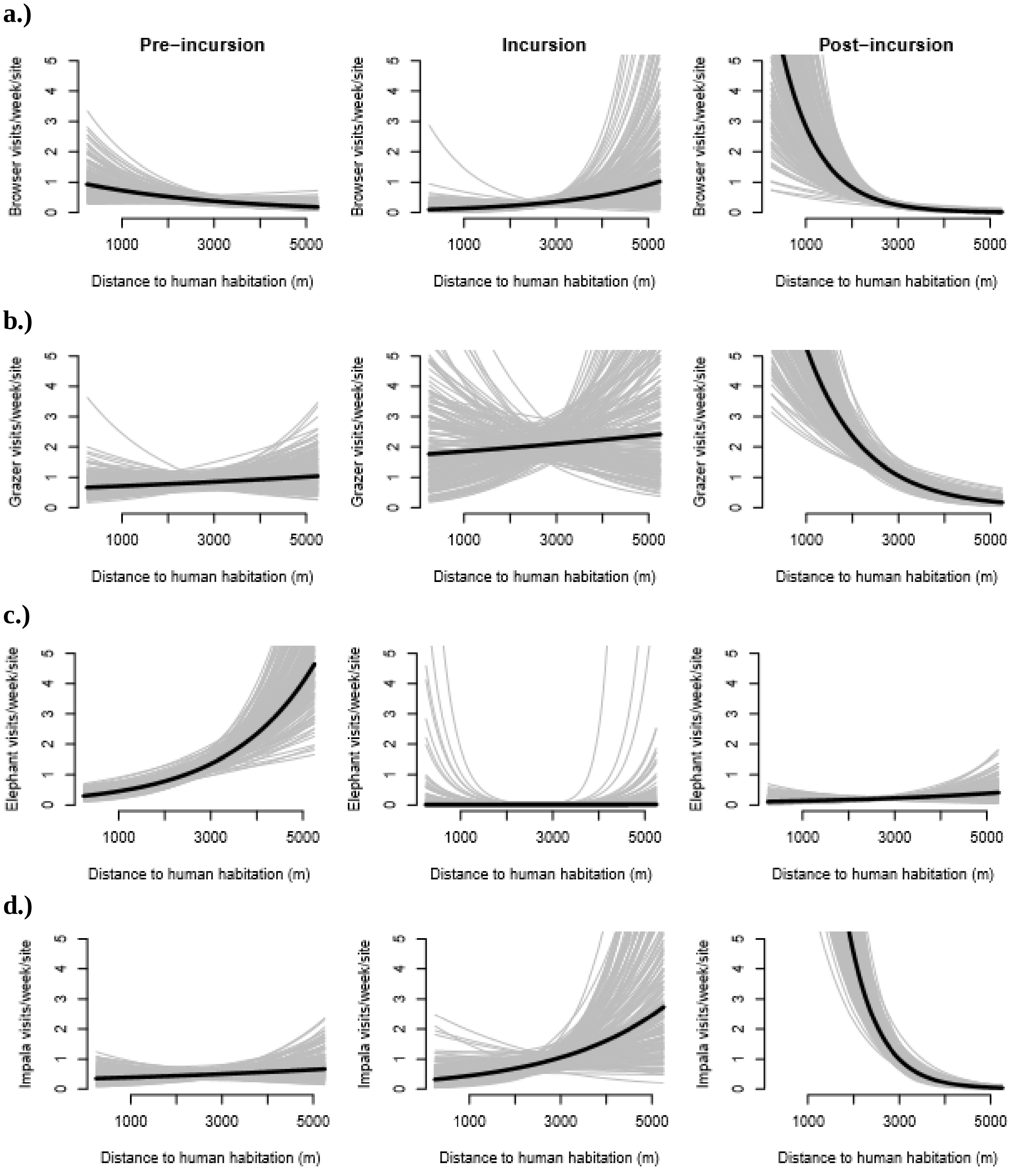


Figure. A5. Plots of the effects of distance to river on site visitation rates for a) browsers, b) grazers, c) mixed feeder – elephants, and d) mixed feeder - impala from the site visitation model fit to data across 53 sites in Loisaba Conservancy, Kenya, between May 2016 and October 2017. The gray lines represent predictions from a random posterior sample of 200 iterations so to depict uncertainty**.**

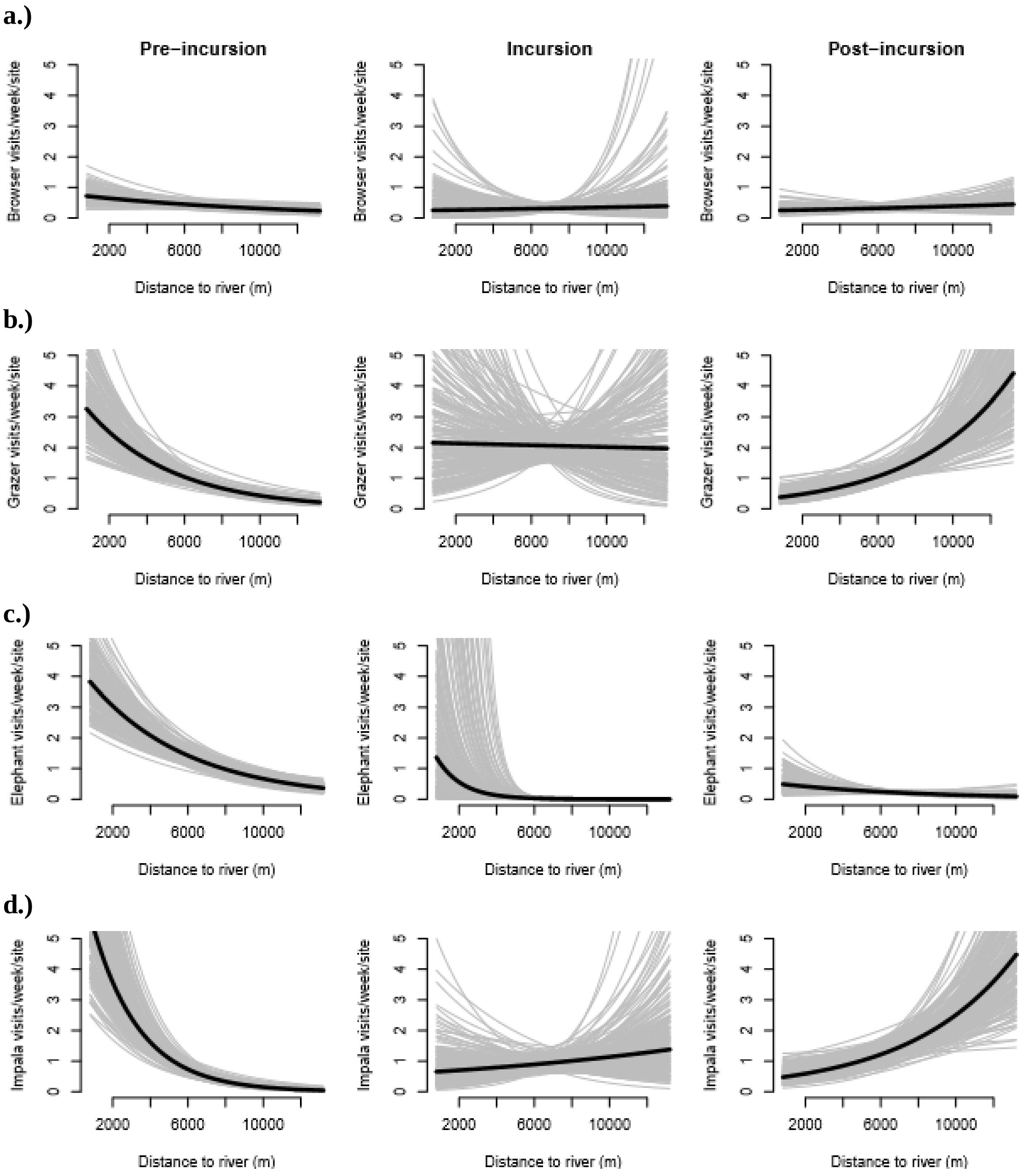
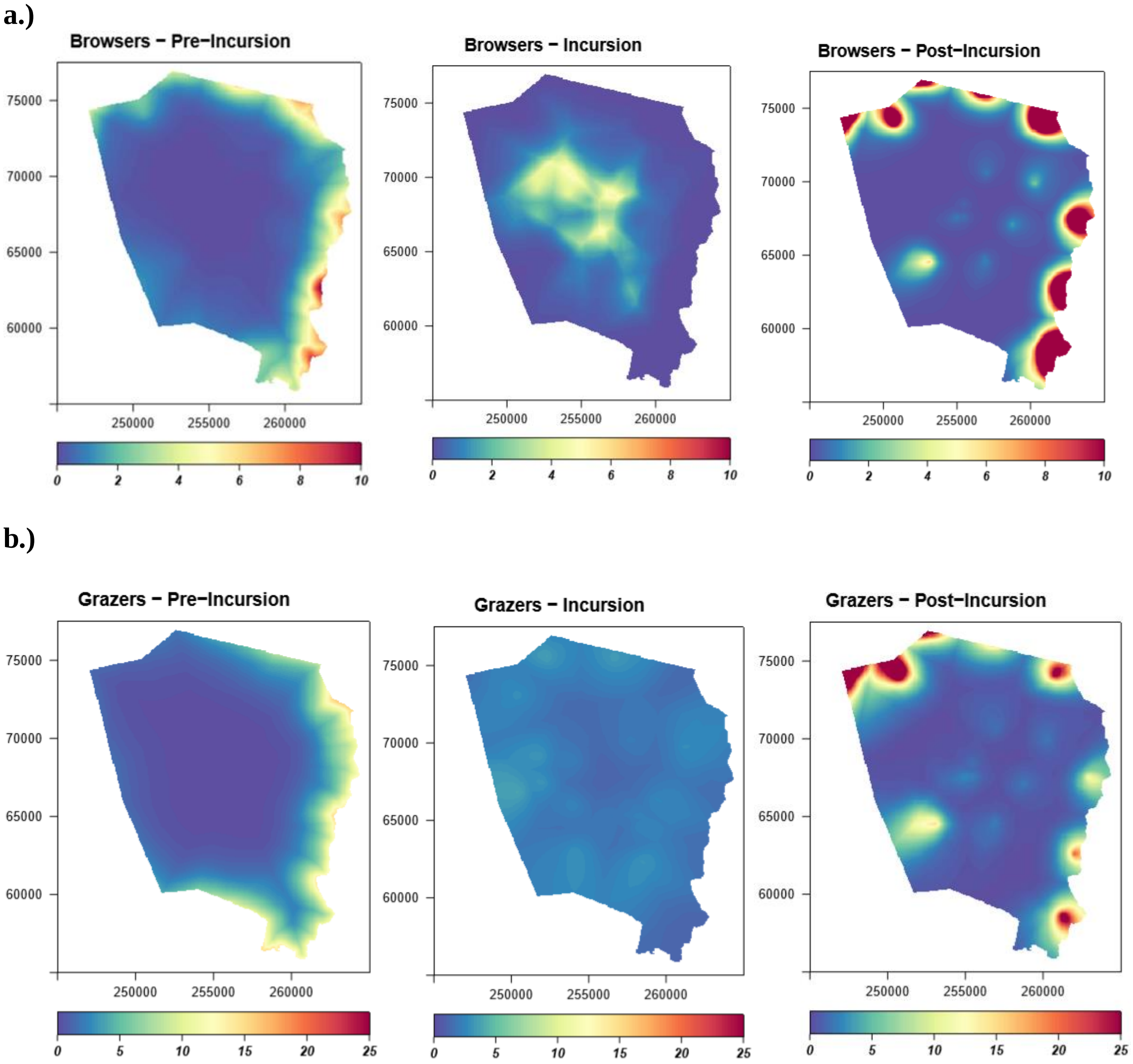


Figure. A6. Spatial predictions of site visitation rates for a) browsers, b) grazers, c) mixed feeder - elephants, and d) mixed feeder-impala from a model fit to data across 53 sites in Loisaba Conservancy, Kenya, between May 2016 and October 2017. The X and Y axes are representative of UTM coordinates. Site visitation rate axes vary among plots**.**



Browsers − Pre−Incursion

Browsers − Incursion

Browsers − Post−Incursion

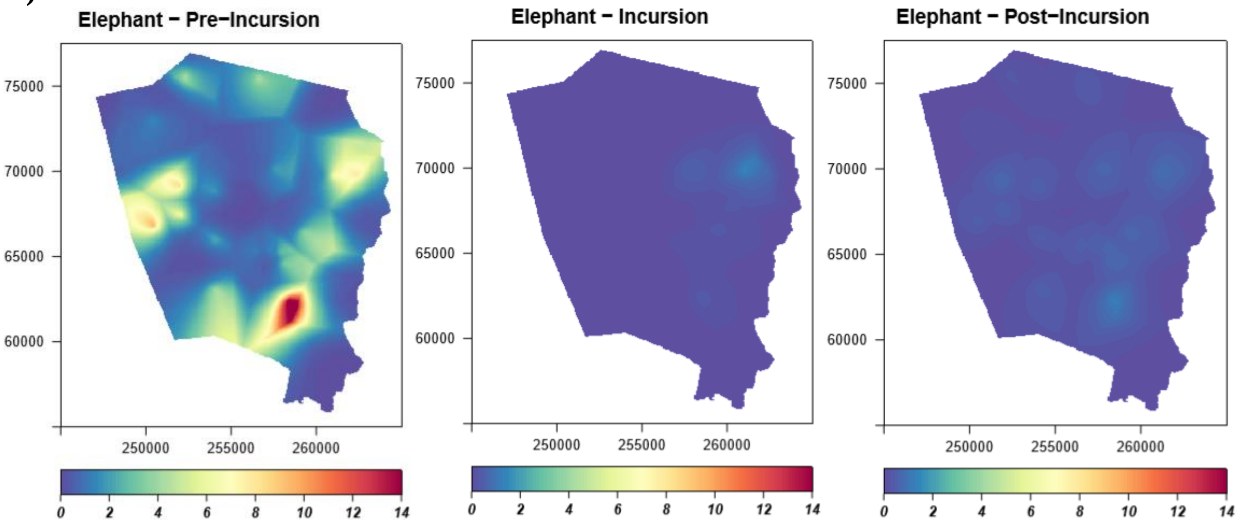
Grazers − Pre−Incursion

Grazers − Incursion

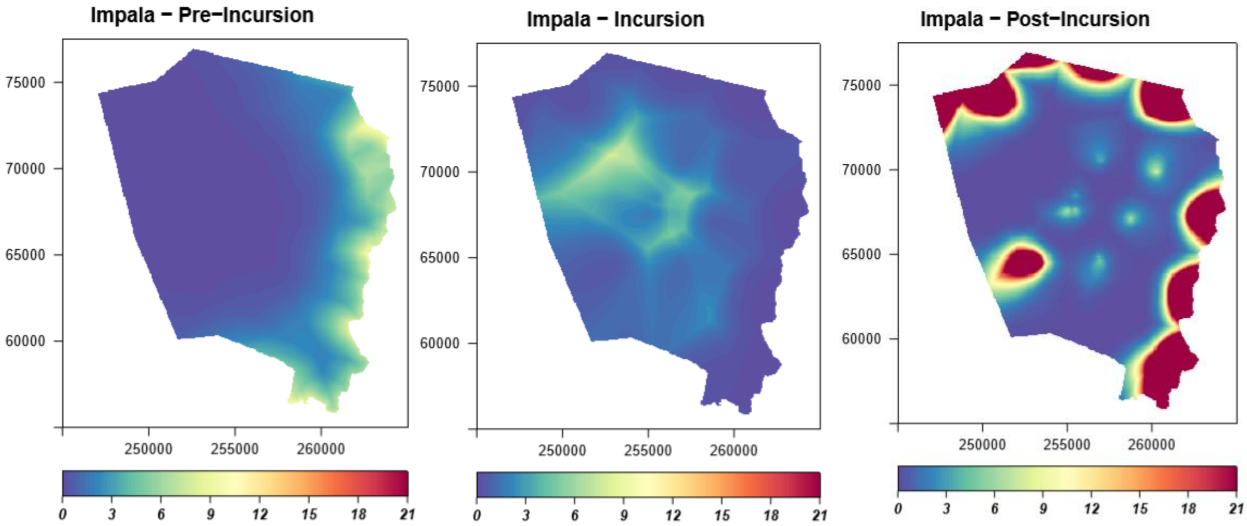
Grazers − Post−Incursion

Figure A6. (cont'd).

c.)



d.)



Appendix A. JAGS model code and spline correlgorams of model residuals from a Bayesian site visitation model fit to data from 53 sites in Loisaba Conservancy, Kenya, between May 2016 and October 2017.

```
 # jags model
   model {

      # Site visit priors
      int ~ dnorm(0,0.1)
      A_riv ~ dnorm(0,0.1)
      A_dam ~ dnorm(0,0.1)
      A_bound ~ dnorm(0,0.1)
      A_hum ~ dnorm(0,0.1)

      A_riv_dur ~ dnorm(0,0.1)
      A_riv_post ~ dnorm(0,0.1)

      A_dam_dur ~ dnorm(0,0.1)
      A_dam_post ~ dnorm(0,0.1)

      A_bound_dur ~ dnorm(0,0.1)
      A_bound_post ~ dnorm(0,0.1)

      A_hum_dur ~ dnorm(0,0.1)
      A_hum_post ~ dnorm(0,0.1)

      A_treat[1] <- 0 # Reference category
      for (k in 2:3) {
      A_treat[k] ~ dnorm(0,0.1)
      }

      # priors on gamma
      alpha<-exp(logalpha)
      logalpha ~ dunif(-5,5)

      # Likelihood
      # Loop over rows (sites)
      for (i in 1:R) {

      # Loop over columns (replicate periods)
      for (j in 1:T) {

    y[i,j] ~ dpois(mustar[i,j])
    mustar[i,j] <- rho[i,j]*mu[i,j]
    rho[i,j] ~ dgamma(alpha,alpha)

      log(mu[i,j]) <- int +
      A_treat[treatment[j]] +
```

```
A_riv * d_riv[i] +
A_dam * d_dam[i]+
A_bound * d_bounde[i]+
A_hum * d_hum[i] +

A_riv_dur* equals(TREATMENT[j],2) *d_riv[i] +
A_riv_post* equals(TREATMENT[j],3) *d_riv[i] +

A_dam_dur* equals(TREATMENT[j],2) *d_dam[i] +
A_dam_post* equals(TREATMENT[j],3) *d_dam[i] +

A_bound_dur* equals(TREATMENT[j],2) *d_bound[i] +
A_bound_post* equals(TREATMENT[j],3) *d_bound[i] +

A_hum_dur* equals(TREATMENT[j],2) *d_hum[i] +
A_hum_post* equals(TREATMENT[j],3) *d_hum[i]

} #j
} #i
}
```

Figure. A7. Spline correlograms of model residuals for a) browsers, b) grazers, c) mixed feeder – elephants, and d) mixed feeder - impala. The distance on the x-axis represents kilometers between paired locations. The plots depict mean correlation and a 95% confidence envelope. For all browser, grazer, and mixed feeder (elephant and impala) model residuals, the confidence envelope overlaps zero at all distances, indicating a complete lack of autocorrelation.

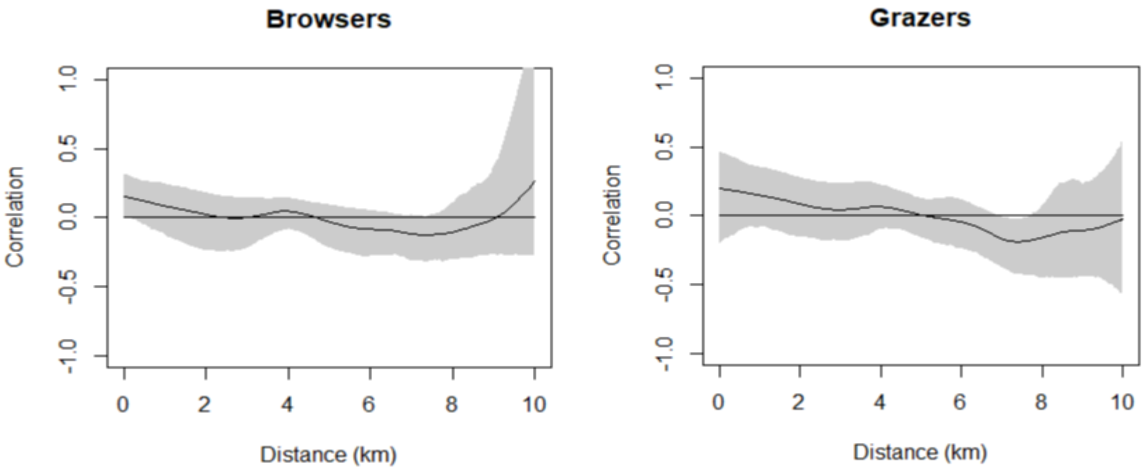
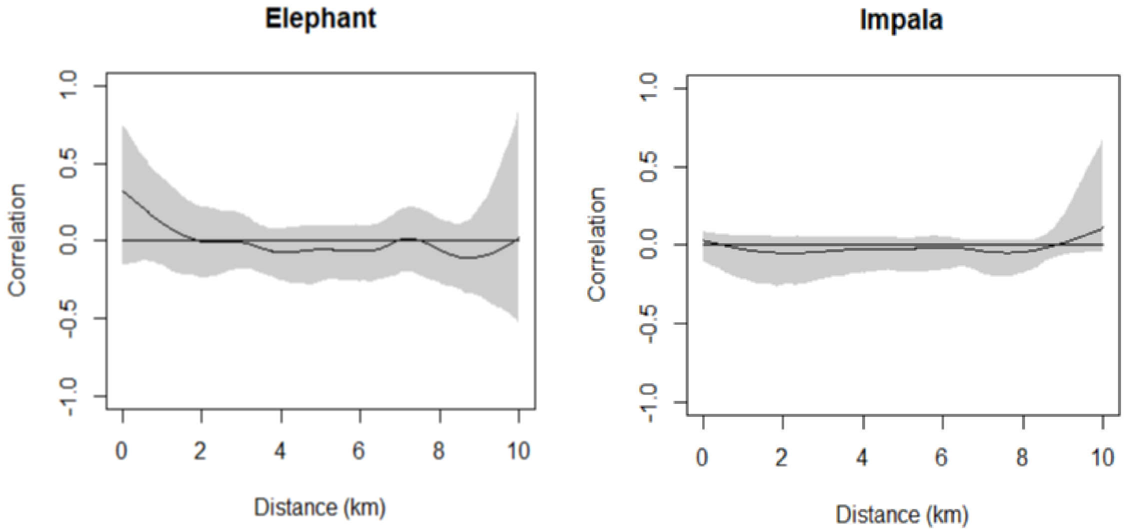


Figure. A7. (Cont'd)



REFERENCES

REFERENCES

Abrams, P. (1983). The theory of limiting similarity. Annual review of ecology and systematics, 14(1), 359-376.

Akama, J. S. (2002). The role of government in the development of tourism in Kenya. International Journal of Tourism Research, 4(1), 1-14

Ameso, E., Bukachi, S., Olungah, C., Haller, T., Wandibba, S., & Nangendo, S. (2018). Pastoral Resilience among the Maasai Pastoralists of Laikipia County, Kenya. Land. https://doi.org/10.3390/land702007

Anderson, T. M., White, S., Davis, B., Erhardt, R., Palmer, M., Swanson, A., ... & Packer, C. (2016). The spatial distribution of African savannah herbivores: species associations and habitat occupancy in a landscape context. Philosophical Transactions of the Royal Society B: Biological Sciences, 371(1703), 20150314.

Archer, S. R. (2010). Rangeland conservation and shrub encroachment: new perspectives on an old problem. Wild rangelands: Conserving wildlife while maintaining livestock in semi-arid ecosystems, 53-97.

Ashiagbor, G., & Danquah, E. (2017). Seasonal habitat uses by Elephants (Loxodonta africana) in the Mole National Park of Ghana. Ecology and evolution, 7(11), 3784-3795.

Averbeck, C., Apio, A., Plath, M., & Wronski, T. (2009). Environmental parameters and anthropogenic effects predicting the spatial distribution of wild ungulates in the Akagera savannah ecosystem. African Journal of Ecology, 47(4), 756-766.

Balmford, A., Green, R. E., & Jenkins, M. (2003). Measuring the changing state of nature. Trends in Ecology & Evolution, 18(7), 326-330.

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O., Swartz, B., Quental, T. B., ... & Mersey, B. (2011). Has the Earth's sixth mass extinction already arrived? Nature, 471(7336), 51.

Bedunah, D. J., & Harris, R. B. (2016). Past, present and future: rangelands in China. Rangelands. https://doi.org/10.2458/azu_rangelands_v24i4_bedunah

Beekman, J. H., & Prins, H. H. T. (1989). Feeding strategies of sedentary large herbivores in East Africa, with emphasis on the African buffalo, Syncerus coffer. African Journal of Ecology, 27(2), 129-147.

Bilotta, G. S., Brazier, R. E., & Haygarth, P. M. (2007). The Impacts of Grazing Animals on the Quality of Soils, Vegetation, and Surface Waters in Intensively Managed Grasslands. Advances in Agronomy. https://doi.org/10.1016/S0065-2113(06)94006-1

Blench, R. (2001). 'You Can't Go Home Again': Pastoralism in the New Millennium (p. 103). London: Overseas Development Institute.

Blench, R., & Sommer, F. (1999). Understanding rangeland biodiversity. Overseas Development Institute Working Paper 121.

Böhm, M., Hutchings, M. R., & White, P. C. L. (2009). Contact networks in a wildlife-livestock host community: Identifying high-risk individuals in the transmission of bovine TB among badgers and cattle. PLoS ONE. https://doi.org/10.1371/journal.pone.0005016

Bonny, S. P., Gardner, G. E., Pethick, D. W., & Hocquette, J. F. (2015). What is artificial meat and what does it mean for the future of the meat industry? Journal of Integrative Agriculture, 14(2), 255-263.

Burton, A. C., Neilson, E., Moreira, D., Ladle, A., Steenweg, R., Fisher, J. T., … Boutin, S. (2015). Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. Journal of Applied Ecology, 52, 675–685.

Butt, B. (2010). Pastoral resource access and utilization: Quantifying the spatial and temporal relationships between livestock mobility, density and biomass availability in southern Kenya. Land Degradation and Development, 21(6), 520–539.

Butt B and M. D. Turner, (2012) “Clarifying competition: the case of wildlife and pastoral livestock in East Africa,” Pastoralism, vol. 2, no. 1, article no. 9, 2012.

Catarrh, M. (2012). Malignant Catarrhal Fever Malignant Catarrh, Malignant Head Catarrh, Gangrenous Coryza, Catarrhal.

Ceballos G, Ehrlich PR (2002). Mammal population losses and the extinction crisis. Science. 2002; 296:904–907

Cleaveland, S., Kusiluka, L., Ole Kuwai, J., Bell, C., & Kazwala, R. (2001). Assessing the impact of malignant catarrhal fever in Ngorongoro District, Tanzania. A study commissioned by the Animal Health Programme of the United Kingdom Department for International Development

Codron, D., Codron, J., Lee-Thorp, J. A., Sponheimer, M., de Ruiter, D., Sealy, J., … Fourie, N. (2007). Diets of savanna ungulates from stable carbon isotope composition of faeces. J. Zool. https://doi.org/10.1111/j.1469-7998.2007.00292

Coppock, D. L., Swift, D. M., & Ellis, J. E. (1986). Livestock Feeding Ecology and Resource Utilization in a Nomadic Pastoral Ecosystem. The Journal of Applied Ecology.

Dettenmaier, S. J., Messmer, T. A., Hovick, T. J., & Dahlgren, D. K. (2017). Effects of livestock grazing on rangeland biodiversity: A meta-analysis of grouse populations. Ecology and evolution, 7(19), 7620-7627.

Devendra, C., & Thomas, D. (2002). Crop–animal systems in Asia: importance of livestock and characterization of agro-ecological zones. Agricultural Systems, 71(1-2), 5-15

Didier, K. A., Cotterill, A., Douglas-Hamilton, I., Frank, L., Georgiadis, N. J., Graham, M., ... & Wilkie, D. (2011). Landscape-scale conservation planning of the Ewaso Nyiro: a model for land use planning in Kenya? Smithsonian Contributions to Zoology.

Dong, S. (2016). Overview: Pastoralism in the world. In building resilience of human-natural systems of pastoralism in the developing world (pp. 1-37). Springer, Cham.

Douglas-Hamilton, I., Krink, T., & Vollrath, F. (2005). Movements and corridors of African elephants in relation to protected areas. Naturwissenschaften, 92(4), 158-163.

Eccard, J. A., Walther, R. B., & Milton, S. J. (2000). How livestock grazing affects vegetation structures and small mammal distribution in the semi-arid Karoo. Journal of Arid Environments. https://doi.org/10.1006/jare.2000.0659

Egeru, A. (2016). Climate risk management information, sources and responses in a pastoral region in East Africa. Climate Risk Management, 11, 1-14.

Ellis J, Galvin KA (1994) Climate patterns and land-use practices in the dry zones of Africa. Bioscience, 44: 340–349. 10.2307/1312384

FAO, (2001). Pastoralism in the new millennium. FAO Animal Production and Health Paper 150. Rome, Italy.

FAO (2009). The State of Food and Agriculture 2009: Livestock in the balance. FAO Rome.

Food and Agriculture Organization (FAO). (2009). How to Feed the World in 2050? Insights from an Expert Meeting at FAO. https://doi.org/10.1111/j.1728-4457.2009.00312.x

FAO (2011) Global meat consumption to rise 73 percent by 2050:

Fenner, F. J., P. J. Gibbs, F. A. Murphy, R. Rott, M. J. Studdert, and D. O. White. 1993. Veterinary virology, p. 403-430. Academic Press, New York, N.Y.

Fryxell, J. M., Wilmshurst, J. F., & Sinclair, A. R. E. (2004). Predictive models of movement by serengeti grazers. Ecology.

Fritz, H. M. De Garine - Wichatitsky, and G. Letessier, “Habitat use by sympatric wild and domestic herbivores in an African savanna woodland: The influence of cattle spatial behaviour,” Journal of Applied Ecology, vol. 33, no. 3, pp. 589–598, 1996

Gadd, M. E. (2005). Conservation outside of parks: Attitudes of local people in Laikipia, Kenya. Environmental Conservation.

Galvin, K. A., Reid, R. S., Behnke, R. H., & Hobbs, N. T. (2008). Fragmentation in semi-arid and arid landscapes. Consequences for Human and Natural Systems. Consequences for Human and Natural Systems. https://doi.org/10.1007/978-1-4020-4906-4

Gause, G. F. (1934). Experimental analysis of Vito Volterra's mathematical theory of the struggle for existence. Science, 79(2036), 16-17

Gelman, A., & Hill, J. (2007). Data analysis using regression and multilevel/hierarchical models. New York, New York: Cambridge University Press.

Georgiadis, N. J., Olwero, J. G. N., Ojwang', G., & Romañach, S. S. (2007). Savanna herbivore dynamics in a livestock-dominated landscape: I. Dependence on land use, rainfall, density, and time. Biological Conservation, 137(3), 461–472.

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., ... & Tempio, G. (2013). Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO

Goheen, J. R., Palmer, T. M., Keesing, F., Riginos, C., & Young, T. P. (2010). Large herbivores facilitate savanna tree establishment via diverse and indirect pathways. Journal of Animal Ecology. https://doi.org/10.1111/j.1365-2656.2009.01644.x

Goheen, J. R., Augustine, D. J., Veblen, K. E., Kimuyu, D. M., Palmer, T. M., Porensky, L. M., Young, T. P. (2018). Conservation lessons from large-mammal manipulations in East African savannas: The KLEE, UHURU, and GLADE experiments. Annals of the New York Academy of Sciences.

Gordon, I. J. (1988). Facilitation of red deer grazing by cattle and its impact on red deer performance. Journal of Applied Ecology, 25(1), 1-10

Gordon, I. J. (2003). Browsing and grazing ruminants: Are they different beasts? Forest Ecology and Management. https://doi.org/10.1016/S0378-1127(03)00124-5

Gortázar, C., Ferroglio, E., Höfle, U., Frölich, K., & Vicente, J. (2007). Diseases shared between wildlife and livestock: A European perspective. European Journal of Wildlife Research. https://doi.org/10.1007/s10344-007-0098-y

Greene, W. (2008). Functional forms for the negative binomial model for count data. Economics Letters, 99(3), 585-590.

Guo, K., Liu, H., Bao, H., Hu, J., Wang, S., Zhang, W., … Jiang, G. (2017). Habitat selection and their interspecific interactions for mammal assemblage in the Greater Khingan Mountains, northeastern China. Wildlife Biology. https://doi.org/10.2981/wlb.00261

Hebblewhite, M., Merrill, E., & McDermid, G. (2008). A Multi-Scale Test of the Forage Maturation Hypothesis in a Partially Migratory Ungulate Population. Ecological Monographs, 78(2), 141–166.

Hempson, G. P., Archibald, S., & Bond, W. J. (2017). The consequences of replacing wildlife with livestock in Africa. Scientific Reports. https://doi.org/10.1038/s41598-017-17348-4

Herrero, M., & Thornton, P. K. (2010). Mixed crop livestock systems in the developing world: present and future. Advances in Animal Biosciences, 1(2), 481–482.

Hibert, F., Calenge, C., Fritz, H. et al. Biodivers Conserv (2010) 19: 2003. https://doi.org/10.1007/s10531-010-9822-0

Holechek, J. L., R. D. Pleper, and C. H. Herbel. 1995. Range Management Principles and Practices. 2nd Edition. Prentice- Hall, Englewood Cliffs, N.J.

Homewood, K. M., Trench, P. C., & Brockington, D. (2012). Pastoralist livelihoods and wildlife revenues in East Africa: a case for coexistence? Pastoralism: Research, Policy and Practice, 2(1), 19.

Hopcraft, J. G. C., Morales, J. M., Beyer, H. L., Haydon, D. T., Borner, M., Sinclair, A. R. E., & Olff, H. (2010). Serengeti Wildebeest and Zebra Migrations are affected Differently by Food Resources and Predation Risks. Groningen Ecological.

IFAD (2008) Livestock and pastoralists. http://www.ifad.org/lrkm/factsheet/pastoral-ists.

Jamal, S. M., & Belsham, G. J. (2013). Foot-and-mouth disease: past, present and future. Veterinary research, 44(1), 116.

Kassahun A, Snyman HA, Smit GN (2008) Impact of rangeland degradation on the pastoral production systems, livelihoods and perceptions of the Somali pastoralists in Eastern Ethiopia. Journal of Arid Environments 72: 1265–1281

Kauffman, J. B., & Pyke, D. A. (2001). Range ecology, global livestock influences. Elsevier 330-344

Kays, R., Parsons, A. W., Baker, M. C., Kalies, E. L., Forrester, T., Costello, R., … Mcshea, W. J. (2016). Does hunting or hiking affect wildlife communities in protected areas? Journal of Applied Ecology, 54(1), 242–252. doi:10.1111/1365-2664.12700

Keine, A. (2009). Desertification- its effects on people and land. World Ecology Report, 21(1), 1–6. Retrieved from http://worldinfo.org/wp-content/uploads/library/wer/english/2009_Spring_Vol_XXI_no_1.pdf

Kenya National Bureau of Statistics (KNBS 2009). Kenya Demographic Survey 2008-09.

Kerven, C., Steimann, B., Ashley, L., Dear, C., & Rahim, I. (2011). Pastoralism and farming in Central Asia's Mountains: a research review (pp. 1-60). Mountain Soc. Research Inst.(MSRI), University of Central Asia.

Kéry, M., & Royle, J. A. (2015). Applied Hierarchical Modeling in Ecology: Analysis of distribution, abundance and species richness in R and BUGS: Volume 1: Prelude and Static Models. Academic Press.

Kimman, T., Hoek, M., & De Jong, M. C. M. (2013). Assessing and controlling health risks from animal husbandry. NJAS - Wageningen Journal of Life Sciences.

Kinga, G. W., Mironga, J., & Odadi, W. O. (2018). Analysis of the Spatial Relationship between Cattle and Wild Ungulates across Different Land-Use Systems in a Tropical Savanna Landscape. International Journal of Ecology.

Krausman, P. R., Naugle, D. E., Frisina, M. R., Northrup, R., Bleich, V. C., Block, W. M., … Wright, J. D. (2009). Livestock grazing, wildlife habitat, and rangeland values. Rangelands. https://doi.org/10.2111/1551-501X-31.5.15

Krätli, S. (2001). Education provision to nomadic pastoralists: A literature review.

Landman, M., Kloppers, K., & Kerley, G. I. (2018). Settling the browser-grazer debate for African buffalo in grass-limited Eastern Cape thicket, South Africa. Koedoe, 60(1), 1-4.

Lankester, F., & Davis, A. (2016). Pastoralism and wildlife: historical and current perspectives in the East African rangelands of Kenya and Tanzania. Revue Scientifique ET Technique de l'OIE, 35(2), 473–484.

Leff, J. (2009). Pastoralists at War: Violence and Security in the Kenya-Sudan-Uganda Border Region. International Journal of Conflict and Violence, 3(2), 188–203.

Lengoiboni, M., van der Molen, P., & Bregt, A. K. (2011). Pastoralism within the cadastral system: Seasonal interactions and access agreements between pastoralists and non-pastoralists in Northern Kenya. Journal of Arid Environments, 75(5), 477–486.

Liu, J., Feng, C., Wang, D., Wang, L., Wilsey, B. J., & Zhong, Z. (2015). Impacts of grazing by different large herbivores in grassland depend on plant species diversity. Journal of Applied Ecology, 52(4), 1053-1062.

Low, B., Sundaresan, S. R., Fischhoff, I. R., & Rubenstein, D. I. (2009). Partnering with local communities to identify conservation priorities for endangered Grevy's zebra. Biological Conservation, 142(7), 1548-1555.

Lund, H. G. (2007). Accounting for the world's rangelands. Rangelands, 29(1), 3-11.

MacArthur, R., & Levins, R. (1967). The limiting similarity, convergence, and divergence of coexisting species. The American Naturalist, 101(921), 377-385.

Machovina, B., Feeley, K. J., & Ripple, W. J. (2015). Biodiversity conservation: The key is reducing meat consumption. Science of the Total Environment, 536, 419–431.

Maitra, T. (2010). Livestock and the Environment. SSRN. https://doi.org/10.2139/ssrn.1620866

Manasseh Wepundi, Eliud Nthiga, Eliud Kabuu, Ryan Murray, and Anna Alvazzi del Frate (2012). Availability of Small Arms and Perceptions of Security in Kenya: An Assessment. Special report

Mason, T. H. E., Pollard, C. R. J., Chimalakonda, D., Guerrero, A. M., Kerr-Smith, C., Milheiras, S. A. G., … Bunnefeld, N. (2018). Wicked conflict: Using wicked problem thinking for holistic management of conservation conflict. Conservation Letters. https://doi.org/10.1111/conl.12460

McNaughton, S. A., & Georgiadis, N. J. (1986). Ecology of African grazing and browsing mammals. Annual review of ecology and systematics, 17(1), 39-66.

Mishra, C., Van Wieren, S. E., Ketner, P., Heitkönig, I. M., & Prins, H. H. (2004). Competition between domestic livestock and wild bharal Pseudois nayaur in the Indian Trans-Himalaya. Journal of Applied Ecology, 41(2), 344-354.

Mishra, C., Van Wieren, S. E., Heitkönig, I. M., & Prins, H. H. (2002, August). A theoretical analysis of competitive exclusion in a Trans-Himalayan large-herbivore assemblage. In Animal Conservation forum (Vol. 5, No. 3, pp. 251-258). Cambridge University Press

Moktan, M. R., Norbu, L., Nirola, H., Dukpa, K., Rai, T. B., & Dorji, R. (2008). Ecological and social aspects of transhumant herding in Bhutan. Mountain Research and Development, 28(1), 41-49.

Moll, R. J., Cepek, J. D., Lorch, P. D., Dennis, P. M., Robison, T., Millspaugh, J. J., & Montgomery, R. A. (2018). Humans and urban development mediate the sympatry of competing carnivores. Urban Ecosystems, 21, 765–778.

Mose, V. N., Nguyen-Huu, T., Western, D., Auger, P., & Nyandwi, C. (2013). Modelling the dynamics of migrations for large herbivore populations in the Amboseli National Park, Kenya. Ecological Modelling, 254, 43–49.

Nelson, F. (2012). Natural conservationists? Evaluating the impact of pastoralist land use practices on Tanzania's wildlife economy. Pastoralism: Research, Policy and Practice, 2(1), 15.

Ngeiywa, B. K. (2008). Deterring Cross-Border Conflict in the Horn of Africa: A Case Study of Kenya-Uganda Border. NAVAL POSTGRADUATE SCHOOL MONTEREY CA.

Niamir-Fuller, M. (1999). Managing mobility in African rangelands. Property rights, risk and livestock development in Africa, 102-31.

Niamir-Fuller, M., Kerven, C., Reid, R., & Milner-Gulland, E. (2012). Co-existence of wildlife and pastoralism on extensive rangelands: competition or compatibility? Pastoralism. https://doi.org/10.1186/2041-7136-2-8

O'Connor, D. A., Butt, B., & Foufopoulos, J. B. (2016). Mapping the ecological footprint of large livestock overlapping with wildlife in Kenyan pastoralist landscapes. African Journal of Ecology, 54(1), 114-117.

Odadi, W. O., Young, T. P., & Okeyo-Owuor, J. B. (2007). Effects of wildlife on cattle diets in Laikipia rangeland, Kenya. Rangeland Ecology and Management, 60(2), 179–185.

Odadi, W. O., Karachi, M. K., Abdulrazak, S. A., & Young, T. P. (2011). African wild ungulates compete with or facilitate cattle depending on season. Science, 333(6050), 1753-1755.

Ogutu, J. O., Piepho, H. P., Dublin, H. T., Bhola, N., & Reid, R. S. (2009). Dynamics of Mara–Serengeti ungulates in relation to land use changes. Journal of Zoology, 278(1), 1-14.

Ogutu, J. O., Piepho, H. P., Said, M. Y., Ojwang, G. O., Njino, L. W., Kifugo, S. C., & Wargute, P. W. (2016). Extreme wildlife declines and concurrent increase in livestock numbers in Kenya: What are the causes? PloS one, 11(9), e0163249.

Ogutu, J. O., Kuloba, B., Piepho, H. P., & Kanga, E. (2017). Wildlife population dynamics in human-dominated landscapes under community-based conservation: The example of Nakuru Wildlife Conservancy, Kenya. PLoS ONE. https://doi.org/10.1371/journal.pone.0169730

Ole Seno, S. K., & Tome, S. (2013). Socioeconomic and Ecological Viability of Pastoralism in Loitokitok District, Southern Kenya. Nomadic Peoples. https://doi.org/10.3167/np.2013.170104

O’Neil D (2011) Pastoralism. http://anthro.palomar.edu/subsistence/sub_3.htm

Olander, L., Wollenberg, E., Tubiello, F., & Herold, M. (2013). Advancing agricultural greenhouse gas quantification *. Environmental Research Letters. https://doi.org/10.1088/1748-9326/8/1/011002

Ontita, E. (2012). Adapting to Climate Change through a Paradigm Shift in Rural Development: The Case of Westgate Conservancy in Samburu County, Kenya.

Otuoma, J., Kinyamario, J., Ekaya, W., Kshatriya, M., & Nyabenge, M. (2009). Effects of human-livestock-wildlife interactions on habitat in an eastern Kenya rangeland. African Journal of Ecology, 47(4), 567–573.

Otuoma, J. (2004). The effect of wildlife -Livestock-Human interactions on Habitat in the Meru Conservation area, Kenya. Lucid Working Paper, 1–44.

Pas, A. (2018). Governing Grazing and Mobility in the Samburu Lowlands, Kenya. Land. https://doi.org/10.3390/land7020041

Papanastasis, V. P. (2009). Restoration of degraded grazing lands through grazing management: Can it work? Restoration Ecology, 17(4), 441–445.

Pérez-Barbería, F. J. (2017). Scaling methane emissions in ruminants and global estimates in wild populations. Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2016.11.175

Plachter, H., & Hampicke, U. (2010). Large-scale livestock Grazing: A management tool for nature conservation. Large-scale Livestock Grazing doi.org/10.1007/978-3-540-68667-5

Plummer, M. (2003, March). JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling. In Proceedings of the 3rd international workshop on distributed statistical computing (Vol. 124, No. 125.10).

Prins, H. H. (1992). The pastoral road to extinction: competition between wildlife and traditional pastoralism in East Africa. Environmental conservation, 19(2), 117-123.

Prins, H. H.., & Voeten, M. M. (1999). Resource partitioning between sympatric wild and domestic herbivores in the Tarangire region of Tanzania. Oecologia.

Prins, H. H. (2000). Competition between wildlife and livestock in Africa. In Wildlife conservation by sustainable use (pp. 51-80). Springer, Dordrecht.

Putman, R. J., Edwards, P. J., Mann, J. C. E., How, R. C., & Hill, S. D. (1989). Vegetational and faunal changes in an area of heavily grazed woodland following relief of grazing. Biological Conservation. https://doi.org/10.1016/0006-3207(89)90017-7

Randolph, T. F., Schelling, E., Grace, D., Nicholson, C. F., Leroy, J. L., Cole, D. C., Ruel, M. (2007). Invited Review: Role of livestock in human nutrition and health for poverty reduction in developing countries. In Journal of Animal Science (Vol. 85, pp. 2788–2800).

Rannestad, O. T., Danielsen, T., Moe, S. R., & Stokke, S. (2006). Adjacent pastoral areas support higher densities of wild ungulates during the wet season than the Lake Mburo National Park in Uganda. Journal of Tropical Ecology, 22(6), 675–683.

R Core Team. (2017). R: A language and environment for statistical computing. Berkeley, California, USA: R Foundation for Statistical Computing.

Redpath, S. M., Young, J., Evely, A., Adams, W. M., Sutherland, W. J., Whitehouse, A., ... &

Gutierrez, R. J. (2013). Understanding and managing conservation conflicts. Trends in ecology & evolution, 28(2), 100-109.

Reid, R. S., & Ellis, J. E. (1995). Impacts of pastoralists on woodlands in South Turkana, Kenya: Livestock-mediated tree recruitment. Ecological Applications, 5(4), 978–992.

Reid R, Rainy ME, Wilson CJ, Harris E, Kruska RL, Waweru MN, MacMillan SA, Worden JS: (2001) Wildlife cluster around pastoral settlements in Africa, creating multiple species associations of wildlife, livestock and people, PLE Science Series # 2. International Livestock Research Institute, Nairobi; 2001.

Reid R, Thornton PK, Kruska R (2004) Loss and fragmentation of habitat for pastoral people and wildlife in east Africa: Concepts and issues. African Journal of Range and Forage Science 2004, 21: 171–181. 10.2989/10220110409485849

Reid, R. S., Bedelian, C., Said, M. Y., Kruska, R. L., Mauricio, R. M., Castel, V., ... & Thornton, P. K. (2010). Global livestock impacts on biodiversity. Livestock in a changing landscape, 1, 111-138

Reid R. S. (2012). Savannas of Our Birth: People, Wildlife, and Change in East Africa. University of California Press.

Rhodes, J. R., McAlpine, C. A., Zuur, A. F., Smith, G. M., & Ieno, E. N. (2009). GLMM applied on the spatial distribution of koalas in a fragmented landscape. In Mixed effects models and extensions in ecology with R (pp. 469–492). New York, New York: Springer.

Rondinini, C. et al. Global habitat suitability models of terrestrial mammals. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 366, 2633–2641 (2011).

Ross, C. (2016). Elephant forage behavior. The Evergreen State College, 3-8.

Rowntree K, Duma M, Kakembo V, Thornes J. 2004. Debunking the myth of overgrazing and soil erosion. Land Degradation and Development 15: 203–214.

Sadler, K., Kerven, C., Calo, M., Manske, M., & Catley, A. (2009). Milk Matters: A literature review of pastoralist nutrition and programming responses. Feinstein International Center, Tufts University and Save the Children, Addis Ababa.

Schieltz, J. M., & Rubenstein, D. I. (2016). Evidence based review: Positive versus negative effects of livestock grazing on wildlife. What do we really know? Environmental Research Letters. https://doi.org/10.1088/1748-9326/11/11/113003

Schmidt, M., & Pearson, O. (2016). Pastoral livelihoods under pressure: Ecological, political and socioeconomic transitions in Afar (Ethiopia). Journal of Arid Environments. https://doi.org/10.1016/j.jaridenv.2015.07.003

Scoones I (1994) New directions in pastoral development in Africa. In Living with uncertainty: New directions in pastoral development in Africa. Edited by: Scoones I. Intermediate Technology Publications Ltd., London; 1994:1–36.

Shorrocks, B. (2007). The Biology of African Savannahs. The Biology of African Savannahs.

Sitters, J., Heitkönig, I. M. A., Holmgren, M., & Ojwang', G. S. O. (2009). Herded cattle and wild grazers partition water but share forage resources during dry years in East African savannas. Biological Conservation, 142(4), 738–750.

Sinclair ARE, Packer C, Mduma S, Fryxell JM (Eds) (2008): Serengeti III: Human impacts on ecosystem dynamics. University of Chicago Press, Chicago; 2008.

Sinclair ARE, Arcese P (Eds): Serengeti II: Dynamics, management, and conservation of an ecosystem. University of Chicago Press, Chicago; 1995

Soofi, M., Ghoddousi, A., Zeppenfeld, T., Shokri, S., Soufi, M., Jafari, A., ... & Chahartaghi, N. R. (2018). Livestock grazing in protected areas and its effects on large mammals in the Hyrcanian forest, Iran. Biological Conservation, 217, 377-382.

Steinfeld, H., Gerber, P., Wassenaar, T. D., Castel, V., Rosales, M., Rosales, M., & de Haan, C. (2006). Livestock's long shadow: environmental issues and options. Food & Agriculture Org.

Stiling, P., & Moon, D. C. (2005). Quality or quantity: The direct and indirect effects of host plants on herbivores and their natural enemies. Oecologia. https://doi.org/10.1007/s00442-004-1739-4

Su, Y. S., & Yajima, M. (2012). R2jags: A Package for Running jags from R. R package version 0.03-08, URL http://CRAN. R-project. org/package= R2jags.

Talbot, L. M. (1986). Demographic factors in resource depletion and environmental degradation in East African rangeland. Population and Development Review, 441-451.

Teitelbaum, C. S., Fagan, W. F., Fleming, C. H., Dressler, G., Calabrese, J. M., Leimgruber, P., & Mueller, T. (2015). How far to go? Determinants of migration distance in land mammals. Ecology Letters, 18(6), 545–552.

Thornton, P. (2002). Mapping poverty and livestock in the developing world (Vol. 1). ILRI (aka ILCA and ILRAD).

Thornton, P. K. (2010). Livestock production: recent trends, future prospects. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1554), 2853-2867.

Thornton, P. K., Ericksen, P. J., Herrero, M., & Challinor, A. J. (2014). Climate variability and vulnerability to climate change: a review. Global change biology, 20(11), 3313-3328.

Tyrrell, P., Russell, S., & Western, D. (2017). Seasonal movements of wildlife and livestock in a heterogeneous pastoral landscape: implications for coexistence and community based conservation. Global Ecology and Conservation, 12, 59-72.

Verlinden, A., Perkins, J. S., Murray, M., & Masunga, G. (1998). How are people affecting the distribution of less migratory wildlife in the southern Kalahari of Botswana? A spatial analysis. Journal of Arid environments, 38(1), 129-141.

Waithaka, J. (2004). Maasai Mara—an ecosystem under siege: An African case study on the societal dimension of rangeland conservation. African Journal of Range and Forage Science, 21(2), 79-88

Walck, J. L., Hidayati, S. N., Dixon, K. W., Thompson, K., & Poschlod, P. (2011). Climate change and plant regeneration from seed. Global Change Biology. https://doi.org/10.1111/j.1365-2486.2010.02368.x

Wang, Y., Allen, M. L., & Wilmers, C. C. (2015). Mesopredator spatial and temporal responses to large predators and human development in the Santa Cruz Mountains of California. Biological Conservation, 190, 23–33. doi:10.1016/j.biocon.2015.05.007

Weiss, J., Gibis, M., Schuh, V., & Salminen, H. (2010). Advances in ingredient and processing systems for meat and meat products. Meat science, 86(1), 196-213.

Wiethoelter, A. K., Beltrán-Alcrudo, D., Kock, R., & Mor, S. M. (2015). Global trends in infectious diseases at the wildlife–livestock interface. Proceedings of the National Academy of Sciences, 112(31), 9662-9667

Western, D., & Finch, V. (1986). Cattle and pastoralism: Survival and production in arid lands. Human Ecology, 14(1), 77–94.

Western, D., Groom, R., & Worden, J. (2009). The impact of subdivision and sedentarization of pastoral lands on wildlife in an African savanna ecosystem. Biological Conservation, 142(11), 2538–2546.

Witt, A. B. R., & Nongogo, A. X. (2011). The impact of fire, and its potential role in limiting the distribution of Bryophyllum delagoense (Crassulaceae) in southern Africa. Biological Invasions, 13(1), 125-133.

World Bank. (2009). Minding the Stock: Bringing Public Policy to Bear on Livestock Sector Development. Report No. 44010-GlB, (44010), 1–92. Young, T. P. (2018). Conservation lessons from large-mammal manipulations in East African savannas: The KLEE, UHURU, and GLADE experiments. Annals of the New York Academy of Sciences.

Xavier da Silva, M., Paviolo, A., Tambosi, L. R., & Pardini, R. (2018). Effectiveness of Protected Areas for biodiversity conservation: Mammal occupancy patterns in the Iguaçu

National Park, Brazil. Journal for Nature Conservation. https://doi.org/10.1016/j.jnc.2017.11.001

Young, T. P., Palmer, T. M., & Gadd, M. E. (2005). Competition and compensation among cattle, zebras, and elephants in a semi-arid savanna in Laikipia, Kenya. Biological conservation, 122(2), 351-359.