ASSESSING THE ECOLOGICAL AND ANTHROPOGENIC FACTORS AFFECTING GIRAFFE SURVIVAL IN EAST AFRICA

By

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A DISSERTATION

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

Fisheries and Wildlife – Doctor of Philosophy

2021

ABSTRACT

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Giraffe (*Giraffa* spp.*)* populations have declined by approximately 35% in the last 30 years, with extinctions documented in seven African countries. This decline has been attributed primarily to ecological and anthropogenic factors. In this dissertation, I assessed the impact that disease and human-interactions with wildlife have had on giraffe populations. In Chapter One, I quantified the severity of a skin disease that manifests as crusty, greyish-brown lesions, and has been recorded in at least seven countries. I positioned my study in Tanzania, which has some of the highest rates of giraffe skin disease (GSD) recorded in Africa. Using photogrammetric analysis of camera trap images and digital photos of known individual giraffes, I classified GSD lesions into categories of none, mild, moderate, and severe. My study demonstrated that camera trap images presented an informative platform for skin disease ecology studies.

In Chapter Two, I evaluated giraffe-lion interactions in Ruaha National Park, where more than 85% of the giraffe population has GSD. The aim of my study was to assess whether GSD may negatively influence the likelihood of giraffes surviving lion predation attempts. Occurrence of lion marks of was higher for adults and males in the giraffe population suggesting that these individuals were more likely to survive lion attacks. I also found that giraffes are an important prey species for lions in Ruaha National Park but GSD severity plays a minor role in influencing likelihood of surviving a lion predation attempt. I further explored the ecological implications of disease ecology on predator-prey interactions.

In Chapter Three, I documented how giraffe body parts are acquired and their intended use (consumptive, trophy, or medicative), in Tsavo Conservation Area, southern Kenya. I conducted semi-structured surveys among 331 households to assess correlations between nine socioeconomic factors and use of giraffe parts. I found that giraffe parts mostly had consumptive and trophy uses. Giraffe parts were predominantly acquired through one-time suppliers, opportunistic access, and widely-known markets. Three variables, namely gender, occupation, and land ownership were significantly and positively correlated with use of giraffe parts. This study detailed the complex nature of poaching and trade of species of conservation concern in coupled human and natural systems.

In Chapter Four, I explored the complex ways in which background conditions in the environment, coupled with previous experience with wildlife risks influences people’s attitudes toward wildlife in Tsavo Conservation Area, southern Kenya. Respondents stated that baboons (*Papio cynocephalus*), elephants (*Loxodonta africana*), and lions (*Panthera leo*) posed the greatest risks to human security and private property. Respondents that experienced previous risks from wildlife in their villages desired those populations to decrease whereas respondents without access to grazing lands for livestock were inclined to see those wildlife populations increase. My study showed that human attitudes toward wildlife in coupled human and natural systems are more complex than previously considered.

I conclude my dissertation by providing considerations for future studies and highlighting the importance of tailoring conservation interventions to the critically important local contexts and traditional knowledge.

Dedicated to
Félicien Murego and Marie Thérèse Nyiransengiumya
Thank you for your sacrifices.

ACKNOWLEDGEMENTS

I am very grateful to the people and institutions that contributed to this research, whose support and input made this work possible and as unproblematic as possible. First, I would like to thank my academic supervisor Dr. Robert Montgomery, who has consistently guided me and provided excellent advice through my graduate school journey starting with my Master's coursework and degree. I am equally grateful to my graduate committee members Drs. Gary Roloff, Dan Kramer, and Matt Hayward for their valuable input and feedback during my research. Their mentorship allowed me to achieve my academic goals and embrace every challenge. I am also thankful to the many co-authors who lent their expertise in this study. Many thanks to my colleagues in the RECaP laboratory who provided useful feedback to make this work easier and were a source of motivation.

I am indebted to Tom and Kathy Leiden, who provided generous support towards my tuition at MSU and fieldwork both in Kenya and Tanzania. I am also grateful to Julian and Steph Fennessy who ensured that I had necessary provisions to complete my research without any interruptions. Generous financial support for this research was also provided by the MasterCard Foundation Scholars Program at Michigan State University (MSU), Giraffe Conservation Foundation, Leiden Conservation Foundation, African Wildlife Foundation, National Geographic Society, and Wildlife Conservation Network. I would also like to thank all the staff at Ruaha Carnivore Project and Ruaha Lion Guardians in Tanzania, and Wildlife Works in Kenya for their incredible support and participation in data collection. I also recognize the assistance provided by TANAPA, TAWIRI, and KWS officials in making this research possible.

I would like to thank all of my friends and collaborators who provided constant encouragement and ensured that my social life remained joyful as I pursued my academic goals. I am privileged to have such wonderful people in my life. My wholehearted gratitude to my family Pierre and Carly Muhoza, Felix Kwizera, and Félicien Murego who have fully supported me through my academic and professional careers, and taken up genuine interest in giraffe conservation. Lastly, I am forever indebted to Wambui Waweru, my beautiful fiancée and life partner who always supported me through difficult and good times, and accompanied me on long drives to Tsavo during portions of my fieldwork. Thank you for being a part of my life.

PREFACE

Three of the four main chapters of this dissertation have been submitted to peer-reviewed journals with co-authors. While I am recorded as the sole author and use the pronoun I in this dissertation, these chapters include contributions from co-authors who participated in different ways during the development of the studies included herein. The citations for these chapters are listed below:

Chapter 1: Muneza, A.B., W. Ortiz-Calo, C. Packer, J.J. Cusack, T. Jones, M.S. Palmer, A. Swanson, M. Kosmala, A.J. Dickman, D.W. Macdonald and R.A. Montgomery. 2019. Quantifying the severity of giraffe skin disease via photogrammetry analysis of camera trap data. *Journal of Wildlife Diseases*, 55:770 – 781.

Chapter 2: Muneza, A.B., D.W. Linden, M.H. Kimaro, A.J. Dickman, D.W. Macdonald, G.J. Roloff, M.W. Hayward and R.A. Montgomery. Exploring the connections between giraffe skin disease and lion predation. *Journal of Zoology*. In review.

Chapter 3: Muneza, A.B., B. Amakobe, S. Kasaine, D.B. Kramer, M. Githiru, G.J. Roloff, M.W. Hayward and R.A. Montgomery. Socioeconomic factors correlating with illegal use of giraffe body parts. *Oryx*. In review.

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INTRODUCTION

A multitude of observational and experimental studies have shown that biodiversity loss is a global challenge that needs to be addressed to maintain healthy ecosystems (Cardillo et al., 2005; Cardinale et al., 2012; Chase et al., 2020). Factors that have led to biodiversity loss include climate change, habitat loss, disease, and human activities such as overexploitation and pollution (Fisher et al., 2009; Horváth et al., 2019; Singh et al., 2021). The extent to which these factors affect some wildlife species has been extensively documented (Clements et al., 2010; Hodgetts et al., 2018). For instance, poaching and ivory trade are widely recognized as the most important threats to the survival of the African bush elephant (*Loxodonta africana*) across their range (Chase et al., 2016; Schlossberg et al., 2020). As such, wildlife conservation authorities typically implement policies and management strategies to address these threats based on documented evidence (Lindsay et al., 2017; Riddle et al., 2010). However, some wildlife species are understudied and prevailing data gaps in their conservation status present challenges to effective management of wild populations (Courchamp et al., 2018).

Giraffes (*Giraffa* spp.) for example, are among Africa's iconic species but have undergone a precipitous decline in the past 35 years, leading to extinction in seven countries (Courchamp et al., 2018; Muller et al., 2018). Among the nine subspecies of giraffes currently recognized by the International Union for the Conservation of Nature (IUCN), five are listed under the 'Threatened' categories of the Red List of species threatened by extinction (Daley, 2019; Muller et al., 2018). For instance, Masai giraffes (*G. c. tippelskirchi*), found mainly in southern Kenya and throughout Tanzania, have declined by more than 50% and are now classified as 'Endangered' on the IUCN Red List (Bolger et al., 2019). This decline has been primarily attributed to habitat loss and fragmentation, illegal hunting, disease, and human encroachment in protected areas (Okello et al., 2015; Strauss et al., 2015). The impact of diseases on giraffe populations and motivations for poaching giraffes however, remain poorly understood (Dunn et al., 2021; Karimuribo et al., 2011). Considering the potential of zoonotic disease transmission and high degree of overlap between Masai giraffe range and community lands, these two factors present two important giraffe conservation challenges.

Giraffes are susceptible to a number of deadly diseases such as rinderpest, lumpy skin disease, and anthrax (Barrett et al., 2006; Hunter and Wallace, 2001; Kaitho et al., 2013). These diseases though, are prevalent in other mammalian species and have been studied extensively (Davies, 1991; Karstad and Kaminjolo, 1978; Woods, 1988). In the past 25 years, a skin disease that manifests as crusty, greyish-brown lesions that ooze pus has been recorded in giraffe populations across their range (Muneza et al., 2016). The etiological agent of the disease remains unknown and as such, the skin disorder is generically referred to as giraffe skin disease (GSD) by researchers who have studied the disease (Kalema, 1996; Mpanduji et al., 2011). Additionally, categorical descriptions of GSD severity are assigned arbitrarily without quantitative analysis (Lee and Bond, 2016). Lesions caused by GSD also present variation in their anatomical location and their severity has been suggested to make giraffes more vulnerable to lion predation (Epaphras et al., 2012; Muneza et al., 2017). However, no study has documented whether GSD has any impact on lion-giraffe interactions.

Anthropogenic disturbances are also thought to have played an important role in the decline of giraffes. For instance, illegal hunting of giraffes has been documented in many range states (Dunn et al., 2021; Strauss et al., 2015). Giraffes are interesting species for poachers to target considering that their body parts are harvested for trophies, consumed as food, or incorporated into traditional medicines (Hall, 2016; Muneza et al., 2018; Nkwame, 2007). The socioeconomic factors that relate with the use of giraffe body parts however, remain poorly understood. Evaluating these factors presents an opportunity to design mitigation efforts that incorporate traditional knowledge, which is one of the tenets integral to human heritage-centered conservation (Montgomery et al., 2020). Another anthropogenic factor central to conservation of giraffes and wildlife broadly, is understanding the variation of people's attitudes towards according to risks posed by wildlife to human security and private property. People who share landscapes with wildlife often experience negative interactions with wildlife, which can lead to conflict (Hoare, 2012; Kretser et al., 2009; McIvor and Conover, 1994). Human response to these interactions can be severe, and potentially scale to have impacts on wildlife populations (Sangay and Vernes, 2008; Swanepoel et al., 2014). As such, understanding the attitudes of people who have prior experience with risks from wildlife, can generate information that is centered around local traditions and heritage, and enhance conservation practice.

This dissertation aims to assess how ecological and anthropogenic factors may have impacted giraffe survival in East Africa. In Chapter One, I photogrammetrically analyzed camera trap images of giraffe from both Ruaha and Serengeti national parks in Tanzania to quantify GSD severity. I validated my results using digital images of known giraffes from Ruaha National Park, which has the highest prevalence rate of GSD recorded among wild populations of giraffes (Muneza et al., 2017, 2016). In Chapter Two, I examined whether GSD may negatively affect the likelihood of giraffes surviving lion predation attempts. I monitored lion hunting behaviour and estimated proportion of the giraffe population with GSD and evidence of lion marks from previous lion predation attempts. In Chapter Three, I conducted semi-structured surveys in Tsavo Conservation Area, southern Kenya, to document the human socioeconomic factors that correlate with use of giraffe body parts. Tsavo Conservation Area experiences high levels of poaching compared to other regions in Kenya (Long et al., 2020). Then in Chapter Four, I assessed the complex ways in which background conditions in the environment and previous experience with wildlife risks informed peoples' attitudes of wildlife. This dissertation concludes with a summary of my key findings and recommendations for future research. Each chapter of this dissertation ends with a section outlining implications of my research for wildlife conservation, giraffe management, and incorporation of local knowledge in conservation practice in East Africa.

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CHAPTER 1: QUANTIFYING THE SEVERITY OF GIRAFFE SKIN DISEASE VIA PHOTOGRAMMETRY ANALYSIS OF CAMERA TRAP DATA

Abstract

Developing techniques to quantify the spread and severity of diseases afflicting wildlife populations is important for disease ecology, animal ecology, and conservation. Giraffes (*Giraffa* spp.) are in the midst of a dramatic decline but it is not known whether disease is playing an important role in broad scale population reductions. A skin disorder referred to as giraffe skin disease (GSD) was recorded in 1995 in one giraffe population in Uganda. Since then, GSD has been detected in 13 populations in seven African countries but good descriptions of the severity of this disease are not available. I photogrammetrically analyzed camera-trap images from both Ruaha and Serengeti National Parks in Tanzania to quantify GSD severity. As GSD afflicts the limbs of giraffes in Tanzania, I quantified severity by measuring the vertical length of the GSD lesion in relation to the total leg length. Applying the Jenks natural breaks algorithm to the lesion proportions that I derived, I classified individual giraffes into disease categories (none, mild, moderate, and severe). Scaling up to the population-level, I predicted the proportion of the Ruaha and Serengeti giraffe populations with mild, moderate, and severe GSD. This study served to demonstrate that camera traps presented an informative platform for examinations of skin disease ecology.

1.1. Introduction

Emerging skin diseases have jeopardized populations of numerous species of conservation concern over the last quarter century. A facial tumor disease has reduced Tasmanian devil (*Sarcophilus harrisii*) populations by as much as 90% and threatens the extirpation of this species across its range (Jones et al. 2007; McCallum et al. 2007, 2009). White nose syndrome, characterized by fungal growth on the face and wings of afflicted bats (*Phyllostomidae* family), is associated with dramatic declines of scores of different bat species throughout North America (Blehert et al. 2009; Frick et al. 2010). Chytridiomycosis is a fungal disease affecting amphibian populations and causes large patches of skin to thicken and slough away, limiting an afflicted animal's ability to regulate osmotically (Voyles et al. 2009). This disease has devastated amphibian populations around the world in what has been called the biggest loss of biodiversity in recent history (Skerratt et al. 2007). Given the evident conservation implications of diseases that present externally (i.e., on the skin), there is a need to develop non-invasive, rapidly-deployable, and highly-scalable techniques that can quantify the prevalence and severity of skin diseases in wildlife populations.

Recent advances in photographic equipment and photogrammetry have expanded the focus of wildlife conservation research. Photogrammetry, the quantification of photographic images, has been used to: measure morphological characteristics of rare and elusive species (Rothman et al. 2008; Willisch et al. 2013), estimate body size and mass of species of conservation importance (Waite et al. 2007; Berger 2012; Meise et al. 2014), and identify individual animals (via interpretation of unique markings) in a population (Bolger et al. 2012; Durban et al. 2015; Zheng et al. 2016). However, this potentially broad photogrammetry toolbox has been rather narrowly applied to questions relating to animal ontogeny, morphology, trait measurement, and the corresponding evolutionary implications of these factors (Berger 2012). The specific scope of this research largely derives from the difficulty of making precise calculations from images that lack a standardized reference scale (de Bruyn et al. 2009). The use of camera traps for studies of wildlife ecology has grown steadily over the last ten years (Rowcliffe et al. 2008; O'Brien and Kinnaird 2011; Swanson et al. 2015) and holds great promise for assessing disease ecology given the ability to quantify animal occurrence and population density for a variety of species in a non-invasive way. But given that animal subjects captured on camera traps lack a reference scale, photogrammetry of images deriving from this technological platform are rare (Hiby et al. 2009). Here, I explored the productive use of camera traps to measure the severity of wildlife diseases that present on the derma of animal subjects.

Giraffe (*Giraffa* spp.) populations have declined by approximately 40% over the past 30 years with an estimated 100,000 remaining individuals in the wild (Muller et al. 2016). Currently, there are nine giraffe subspecies distributed across 21 countries in sub-Saharan Africa and there are ongoing efforts to update the conservation status of all giraffe subspecies. However, recently the status of giraffes as a species was changed from Least Concern to Vulnerable on the International Union for the Conservation of Nature's Red List (Muller et al. 2016). Giraffe population declines are largely attributed to habitat loss, poaching, human encroachment, and limited conservation attention (Giraffe Conservation Foundation 2013). However, emerging diseases, such as giraffe skin disease (GSD) may also be playing an important role in the conservation of giraffes (Epaphras et al. 2012; Muneza et al. 2016).

First detected in a single giraffe population in Uganda in 1995, GSD has now been recorded in 13 giraffe populations across seven African countries where it affects Masai (*Giraffa tippelskirchi*), Nubian (*G. c. camelopardalis*), Angolan (*G. g. angolensis*), and South African (*G.

g. giraffa) giraffe (Muneza et al. 2016). Although GSD exhibits anatomical variation in its manifestation across its distribution, the progression of the disease appears relatively consistent among these different populations. Giraffe skin disease first presents as small nodules on the skin where the hair becomes raised. These nodules develop into scabs that harden and develop into dry, scaly patches. As the disease progresses, the skin becomes itchy and then wrinkles to form large, greyish, alopecic lesions (Epaphras et al. 2012). In very bad cases, cracks form in these lesions resulting in raw fissures that form pus and ooze.

Given the emergent nature of GSD, the factors that cause the disease and how it spreads are as yet unknown. Initial investigations suggest that filarial worms may be involved in the transmission of GSD, though no formal confirmation of etiology or pathogenesis of the disease has been carried out (Karimuribo et al. 2011; Epaphras et al. 2014). It is currently unclear whether GSD directly decreases survival or reproduction of affected individuals, but it is very possible that it makes affected animals more vulnerable to predation. Lions (*Panthera leo*) prey on adult and sub-adult giraffes (Hayward and Kerley 2005), while leopards (*Panthera pardus*) and hyenas (*Crocuta crocuta*) can kill calves (Hayward et al. 2006; Hayward and Kerley 2008). Giraffes are typically very adept at fending off predator attacks by running and kicking (Carter et al. 2013) but individuals with severe GSD appear to move with difficulty, which could make them more susceptible to lions (Epaphras et al. 2012). The disease is very widespread in Tanzania and has been documented in Ruaha National Park, Serengeti National Park, Manyara Ranch Conservancy, Tarangire National Park, and Selous Game Reserve (Karimuribo et al. 2011; Muneza et al. 2016; Fig. 1.1). Ruaha National Park has the highest recorded prevalence of GSD in Africa with 86% of the population afflicted (Epaphras et al. 2012, 2014; Muneza et al.

2017). However, and very importantly, this statistic documents the occurrence (presence or absence) of GSD, rather than its severity.

Only two studies have attempted to describe the severity of GSD. Kalema (1996) suggested that mild GSD involved small skin nodules measuring 2-3 cm with raised hair, moderate GSD was characterized by round or oval patches of lesions measuring 10-16 cm, and severe GSD was associated with raw fissures measuring >16 cm. The most recent study, carried out in northern Tanzania, proposed GSD lesions with a diameter between 1-30 cm as mild GSD, 31-60 cm as moderate GSD, and >60 cm or cracked skin as severe GSD (Bond et al. 2016). However, these descriptions of GSD severity were assigned arbitrarily, without quantitative analysis or statistical justification of the variation between categories. Given the prevalence of GSD across giraffe populations, a robust categorical description is necessary to quantify severity and to determine the ways in which GSD might affect giraffe survival and reproduction. I conducted a photogrammetry analysis of GSD from extensive photo datasets derived from camera trapping surveys across two study sites in Tanzania. I calculated GSD severity in Ruaha National Park, where GSD is most intense (Muneza et al. 2017) and compared those classifications to rates observed in Serengeti National Park. To assess any patterns in the manifestation of GSD, I examined whether the probability of a GSD lesion appearing on one leg of a giraffe varied with the probability of GSD lesions appearing on another leg. I validated camera trap results using high resolution images captured from vehicle-based surveys where individual identification of giraffes was established. My study represented the first quantification of the severity of a skin disease using photogrammetry of camera trap images. My analytical framework is not specific to giraffes and can be used to assess externally-presenting diseases affecting populations of numerous species of wildlife.

1.2. Methods

1.2.1. Study areas

Ruaha National Park is located in the southern highlands of Tanzania (7°30'00"S, 35°00'00"E), where elevation ranges from 696 m to 2,171 m with an ambient temperature varying from 35˚C during the day to 15˚C during the night (NBS 2013). With an area of 20,226 km^2, Ruaha is Tanzania's largest national park (Fig. 1.1) and is considered a priority landscape for large carnivore conservation (Abade et al. 2014). Recent aerial show that the park is home to important populations of Masai giraffe, estimated at 3,525±980 (TAWIRI 2015).

Serengeti National Park is located in northern Tanzania (2°20'00"S, 34°34'00E) and covers 14,800 km^2 in the Mara-Serengeti ecosystem (Fig.1.1; Reed et al. 2009). The average temperature ranges from 30˚C during the day to 15˚C at night and rainfall in the ecosystem is seasonal (NBS 2013). This is a migratory system where up to 1.4 million wildebeest (*Connochaetes taurinus*), zebras (*Equus* sp.), and gazelles (*Gazella* sp.) move between the Mara and Serengeti annually (Holdo et al. 2009). Serengeti National Park supports 5,886 ±1,221 giraffes, one of the largest populations in the country (TAWIRI 2010).

1.2.2. Camera trap data

Long-term camera trap systems were maintained in both Ruaha and Serengeti National Parks for monitoring a variety of ecological phenomena. In Ruaha National Park, three camera trap (HyperFire HC500, Reconyx, Holmen, Wisconsin, USA) grids were maintained by placing cameras along game trails at a ~2 km^2 spacing (Cusack et al. 2015; Fig. 1.1). In Serengeti National Park, a large contiguous camera trap (ScoutGuard SG565 HCO Outdoor Products, Norcross, Georgia, USA) grid was maintained at a 5 km^2 resolution between 2010 and 2013, covering 1,125 km^2 (Swanson et al. 2015; Fig. 1.1). In the laboratory, I filtered all images resulting from these networks. I removed obvious duplicates (i.e., consecutive camera trap triggers of the same individual) where giraffes were detected. Next, I excluded photos that did not show the full extent of all four legs (shoulder joint to hoof) of the giraffe. Thus, my final dataset for analysis included only photos where the giraffe was close enough to the camera trap that GSD, if present, could be detected on each of the four legs, and where the position of the leg afforded photogrammetric analysis (i.e., the leg was straight and no part of the leg was obscured).

1.2.3. Quantifying GSD severity

I used photogrammetry techniques to quantify GSD severity from the camera trap data. In Adobe Photoshop CS6, (Adobe Inc., San Jose, California, USA), I calculated the length of each leg (A) from the shoulder or hip joint to the carpal or tarsal joint and then to the hoof of the optimal images (Willisch et al. 2013; Fig. 1.2). I then measured the length of each GSD patch (a) from the proximal to the distal margin of the lesion. In cases where a giraffe had more than one patch of GSD on a single leg, I measured each individual lesion and summed the lengths of all lesions for each leg. I did not observe separate GSD lesions to vertically overlap and thus, the summed metric was representative of the extent of GSD for a given giraffe. I divided the total length of the lesion (a) by total length of the leg (A) to calculate the proportion (b) of the leg that was covered by GSD lesions ($b = a/A$). I calculated the approximate length of GSD lesions (B) by multiplying the proportion (b) with the average length of a giraffe's leg (L=180cm) based on Christiansen (2002) such that $B = b \times 180$cm.

1.2.4. Statistical analysis

Next, I assessed whether the probability of a GSD lesion appearing on one leg of a giraffe varied with the probability of GSD lesions appearing on another leg. To quantify the extent of statistical dependence among the proportions of GSD on each of the legs of an affected animal, I used the non-parametric Spearman's correlation coefficient (r_s). I evaluated collinearity among all pairwise combinations (i.e. six possible combinations) of giraffe legs and calculated r_s using the following equation:

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

Here, the Spearman's correlation coefficient r_s is calculated as a function of d_i, which is the difference between the ranks of the proportion of the leg covered by GSD lesions, and n is the number of giraffe with GSD lesions on one or more legs.

I then used the highest GSD proportion value recorded among all of the legs of a giraffe to categorize GSD severity. I developed these categories using the Jenks natural breaks algorithm in R statistical software (R Development Core Team 2015). The Jenks natural breaks method determines the breaks between categories (mild, moderate, or severe) by reducing the in-class variance and maximizing the variance between classes (Jenks 1967; De la Torre et al. 2015). To delineate the GSD severity categories, I used data from Ruaha National Park, given that this park has the highest prevalence of GSD recorded (86%; Muneza et al. 2016, 2017). Thus, I consider this dataset to be most representative of the range of GSD severity. I then compared these results to those developed from the camera trap images from Serengeti National Park. I did so to facilitate a comparison of spatial variation in rates of GSD between sites within the same country.

1.2.5. Validation

Individual identification of giraffes was not possible from the camera trap data given that the majority of the photos included only the lower body of the giraffes. Giraffes can be readily identified when the upper body is visible (Muneza et al. 2017), but not from the legs alone. Concerned with bias resulting from the inadvertent estimation of GSD rates from the same giraffe multiple times, I compared the results of camera trapping analysis with an analysis derived from known giraffe data. To obtain these data, I conducted intensive vehicle-based surveys in Ruaha National Park between May and August 2015 with high-resolution photographic equipment to categorize GSD severity among individually-recognizable giraffes (Fig. 1.1; Muneza et al. 2017). Giraffes were photographed in the field using a digital camera (Nikon D300S, Nikon Inc, Tokyo, Japan with an auto-focus-S DX NIKKOR 70-300mm f/3.5 – 5.6 ED VR lens and identified to individuals using Wild-ID 1.0.0 software. From the overall image dataset, I selected one optimal image per individual giraffe. I calculated individual GSD severity using the same photogrammetry techniques that I used on the camera trap images (process detailed above). Using the Kolmogorov-Smirnov (K-S) test, I then compared the histograms of GSD severity derived from camera trap images to those created from the individually-recognized giraffe data to evaluate each technique. Next, I examined whether the two distributions were statistically different using the equation:

$$D_{n,n'} > c(\alpha)\sqrt{\frac{n+n'}{nn'}}$$

where $D_{n,n'}$ is the maximum difference between cumulative distribution of camera trap images (n) and individually-recognized images (n'), and $c = 1.36$ when $\alpha = 0.05$.

1.3. Results

I obtained a total of 395 optimal camera trap images showing four entire legs of a giraffe from Ruaha National Park. Among this sample, 67.8% (268/395) were deemed suitable for photogrammetric analysis. In Serengeti National Park, I identified a total of 303 optimal images, of which 48.5% (147/303) were considered suitable for photogrammetric analysis. Additionally, in my vehicle-based photographic surveys, I captured 563 individual giraffes in Ruaha National Park, of which images from 54.17% (305/563) were deemed suitable for photogrammetric analysis.

Using the camera trap images from Ruaha National Park and Serengeti National Park, I found that lesions of GSD were more prevalent on the front legs than the back legs in both the Ruaha population (48%, 128/267) and the Serengeti population (56%, 83/148) population. There was no case in which a giraffe had lesions on the hind legs but not on the front legs (Fig. 1.3). A further 58% (177/305) giraffes were recorded with GSD lesions on both front legs from the individually-recognized giraffe dataset in Ruaha National Park (Fig. 1.3). Furthermore, only 10 giraffe images from the camera trap data displayed signs of GSD on more than two legs, of which 3% (9/300) were from Ruaha National Park and <1% (1/100) from Serengeti National Park (Fig. 1.3). There were also 3% (9/300) giraffes from the individually-recognized data that had GSD lesions on more than two legs. There were more cases of giraffes with GSD on the back legs in Ruaha National Park, where I recorded a total of five animals with lesions on all four legs (n = 2 from camera trap images and n = 3 from individually-recognized images). In Serengeti National Park, the number of animals with signs of GSD on the front right leg (20%, 29/145) was comparable to the number of animals with GSD lesions on the front left leg (20%, 30/150). In Ruaha National Park however, GSD lesions on the front right were more common

(31%, 83/268) in camera trap images when compared to lesions on the front left leg (15%, 40/268; Fig. 1.3). However, among the individually-recognized images from Ruaha National Park, GSD lesions were more common on the front left leg (22%, 66/300) than on the front right leg (16%, 48/300). Spearman's correlation coefficient tests showed that there was no relationship between the occurrences of GSD lesions on the legs of giraffe (Table 1.1). The test also revealed that there was a very weak association between the front right and front left legs (Table 1.1).

Using the Jenks natural breaks algorithm, I classified giraffes with 0.01% to 16.1% (1.8 to 28.8 cm) of the leg covered by GSD lesions as having mild GSD. Giraffes with 16.2% to 25% (28.9 to 45.0 cm) of the leg covered had moderate GSD and giraffes with lesions covering >25% (>45 cm) of the leg were classified as severe (Table 1.2; Fig. 1.4). Histograms revealed that the predictions of the categories of GSD severity were not statistically different between the camera trap data and the individually-recognized giraffe data in Ruaha National Park with $D_{n',n''}$ (0.3333) < D (0.5552; Fig. 1.5). Furthermore, the histogram developed for the Serengeti camera trap data showed substantially lower GSD severity in Serengeti when compared to Ruaha (Fig. 1.5). The most severe lesion recorded in Ruaha National Park covered 66% of the front right leg of a giraffe, while the most severe case in Serengeti National Park had a lesion which covered 44% of the giraffe's front left leg (Fig. 1.3). Mild lesions of GSD were the most commonly observed form of the disease and the lesions were almost evenly spread between the front right and front left legs in both Ruaha and Serengeti National Parks. In Serengeti National Park, the number of severe lesions on front legs was almost equal. For instance, I recorded 10 giraffes with severe lesions on the front right leg only and nine giraffes with severe lesions on the front left leg only. There were no cases of giraffes with severe GSD lesions on both front legs in Serengeti National Park. In Ruaha National Park, severe lesions were more prevalent on the front right leg (n = 42), compared to the front left, where I recorded severe lesions 25 times (Fig. 1.3). Additionally, three giraffes in Ruaha National Park had severe lesions on both the front right and front left leg, while such a case was not observed in Serengeti National Park.

1.4. Discussion

I established a protocol for non-invasive examination of the severity of a wildlife skin disease using camera trap images and photogrammetry techniques. I did so by assessing an emergent disease affecting giraffe populations in a region of the world (Tanzania) that is a hotspot for this disease (Muneza et al. 2016). To date, most studies report only the occurrence of GSD with severity assigned using arbitrary demarcations between categories (Kalema 1996; Epaphras et al. 2012; Bond et al. 2016). For example, in Ruaha National Park, more than half of the population (51.7%) was estimated to have GSD lesions that were deemed to be severe (>16 cm; Epaphras et al. 2012). This technique for estimating GSD severity, which requires close observation of affected animals, is not only laborious but also narrow in the spatial extent across which it can be applied. Particularly with respect to emergent diseases, it is necessary to assess patterns of disease ecology across large scales with information returned in a timely fashion. My analysis demonstrated the utility of large-scale camera trapping systems and photogrammetry techniques in providing assessments of skin disease severity. These approaches are non-invasive, can be rapidly-deployable, and are applicable to a variety of species. With large repositories of camera trap data becoming increasingly common (Kays et al. 2015), it will be possible to examine spatiotemporal trends in the distribution, prevalence, and severity of disease that present on the derma of affected animals.

My results demonstrated that in both Ruaha and Serengeti National Parks, most cases of GSD detected via camera trap systems were mild. Despite the fact that 86% of the giraffe population in Ruaha National Park has GSD, the majority of these animals have a mild form of the disease. I also found that rates of moderate GSD were approximately comparable between Ruaha and Serengeti National Parks (i.e., 36% in Ruaha National Park and 40% in Serengeti National Park). However, Ruaha National Park had rates of severe GSD that were twice as high as in Serengeti National Park. As much as 86% of the giraffe population in Ruaha National Park has GSD (Muneza et al. 2017), followed closely by Tarangire National Park, where 63% of the population is affected, and then Serengeti National Park with 23% of the population (Muneza et al. 2016). Tarangire is located in between Ruaha and Serengeti National Parks which suggests that GSD might be affected by spatial or environmental factors (Lee and Bond 2016; Bond et al. 2016). More specifically, the declining GSD prevalence with distance from Ruaha National Park in Tanzania supports a theory that GSD in Tanzania could be emanating from Ruaha National Park outward. However, additional research on these different populations would need to be done to fully evaluate this prospect.

I could not find any obvious relationship in GSD manifestation among the different legs of Masai giraffe. Spearman's correlation coefficient (r_s) showed that there was no statistical dependence in the manifestation of GSD. This meant that the probability of a lesion appearing on one leg of a giraffe did not vary with the probability of lesions appearing on another leg. I searched for associations of six different combinations of giraffe legs but found only one weak negative association for one combination (FR and FL). This was particularly interesting given that GSD in Masai giraffes commonly manifests on the forelegs of affected giraffe (Epaphras et al. 2012; Lee and Bond 2016; Muneza et al. 2016). While I did not identify any order or pattern of GSD manifestation, I noted that lesions were much more prevalent on both forelegs when compared to hind legs (Fig. 1.3). This could possibly have been because GSD has been suggested to be caused by filarial worms and further complicated by secondary fungal infections (Epaphras et al. 2014; Lee and Bond 2016). Filarial worms are mostly transmitted by biting insects and giraffes have a long tail which can deter insects from hind legs whereas the forelegs are more exposed (Siegfried 1990). Future studies intending to collect tissue samples to better understand the epidemiology of GSD should focus on the forelegs and survey for biting insects.

It remains unclear whether GSD severity negatively affects the survival and reproduction of affected animals. Giraffes with severe forms of GSD have been suggested to move with increased difficulty, potentially altering their vulnerability to predators (Epaphras et al. 2014). However, in these instances, GSD severity was assigned arbitrarily. Via the application of photogrammetric techniques to camera trap data, I quantitatively derived an index of GSD severity. Providing that camera trap data are available, these techniques can be readily applied to determine temporal and/or spatial variation in skin diseases in animals with identifiable features. I suggest that these techniques, in combination with focal animal observation, can be a means by which to assess the consequences of skin disease severity on wildlife ecology.

Acknowledgements

My thanks to the Leiden Conservation Foundation, Giraffe Conservation Foundation, the American Society of Mammologists, Roger Williams Zoo, and the US Fish and Wildlife Service African Elephant Fund for their generous support of this research. Thanks to A. Mndeme, P. Mtyana, L. Mlawila, and J. Smit (all of Southern Tanzania Elephant Program) for help with camera-trapping and data management. My gratitude to the UK Natural Environment Research Council for purchasing a number of the camera traps used in the study in Ruaha National Park (Grant NE/J016527/1). The Serengeti National Park camera trap survey was supported by NSF grant DEB-1020479, the University of Minnesota Supercomputing Institute, the National Geographic Society, the Alfred P. Sloan Foundation, Explorer's Club, the American Society of Mammalogists, the Minnesota Zoo, and private donations raised during crowdfunding campaigns. My gratitude to the many volunteers who contributed to Snapshot Serengeti classifications to determine images containing giraffes. I also recognize the assistance provided by the Tanzania Commission for Science and Technology, Tanzania National Parks Authority, and Tanzania Wildlife Research Institute officials in making this research possible.

APPENDIX

APPENDIX

Table 1.1. Spearman's correlation coefficient indicating the relationship between the occurrence of GSD lesions on the legs of giraffe. r_s can take values from -1 to +1, where +1 indicates a perfect positive association and -1 signifies a perfect negative association. Values closer to 0 indicate a weak relationship in the manifestation of GSD lesions.

Legs	Spearman's correlation coefficient (r_s)
Front right + Front left	-0.256
Front right + Back right	0.094
Front right + Back left	0.016
Front left + Back left	0.102
Front left + Back right	0.065
Front right & Front left + Back right & Back left	0.101

Table 1.2. Categorization of GSD severity in Ruaha National Park and Serengeti National Park. The Jenks natural breaks used to classify the categories of GSD severity were obtained from optimization of GSD data in Ruaha National Park.

			Ruaha National Park		Serengeti National Park	
Proportion of leg affected by GSD	Approximate length of GSD lesions (cm)*	Category	Count	Proportion of sample population	Count	Proportion of sample population
0.01 to 0.16	1.8 to 28.8	Mild	102	0.38	69	0.47
0.16 to 0.25	28.9 to 45.0	Moderate	96	0.36	59	0.40
>0.25	>45.0	Severe	70	0.26	19	0.13
Total			268		147	

*Calculated using the average length of giraffe legs (180 cm; Christiansen 2002. Note: front and hind legs of giraffes have almost equal length.

Figure 1.1.

Map showing study areas in Serengeti National Park in northern Tanzania and Ruaha National Park in southern Tanzania and sites where camera traps were installed. Camera traps of a similar grid are represented by one color. Inset map: Distribution and prevalence of GSD in conservation areas in Tanzania where the disease has been recorded.

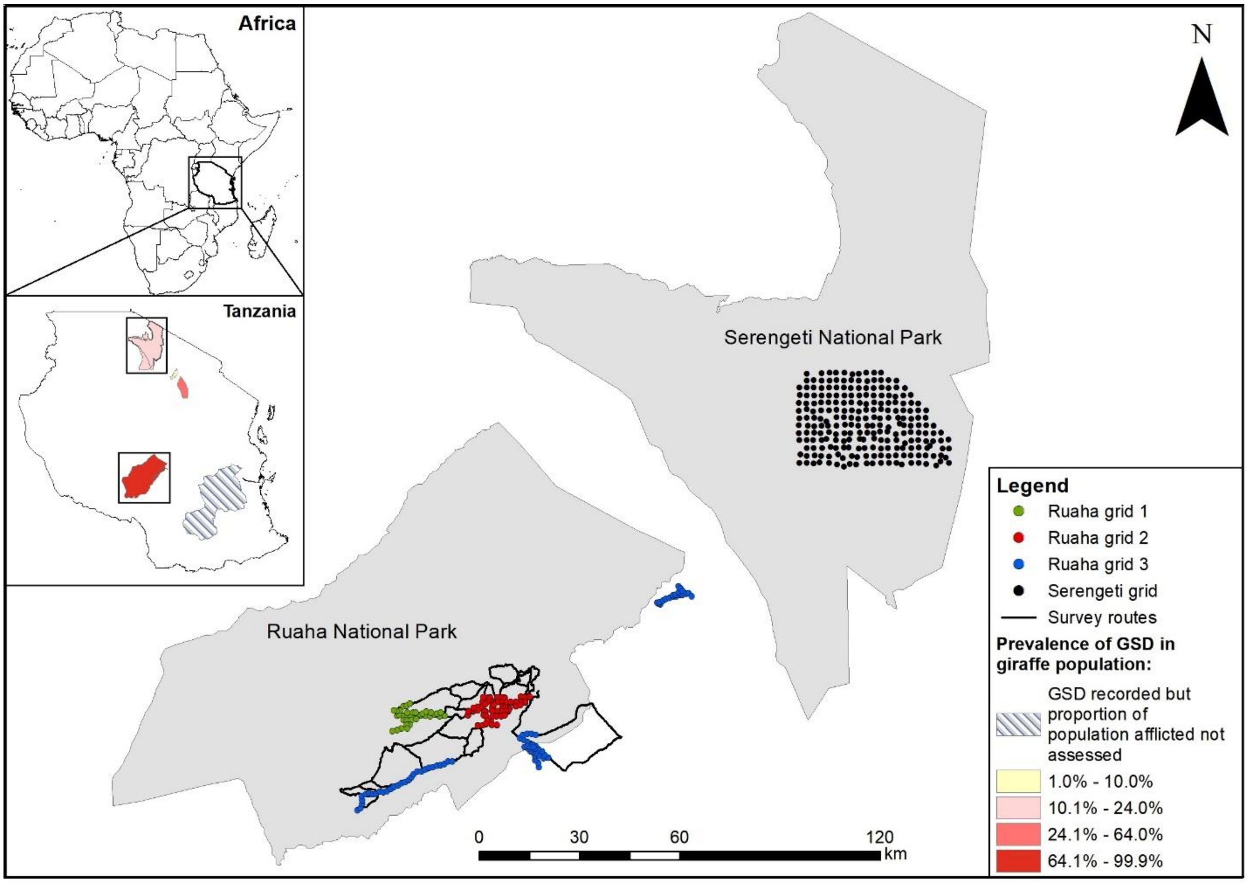


Figure 1.2.

Photogrammetric measurements of giraffe leg length (line A, extending from the humerus to the hoof) and GSD lesions length (line a, extending from the proximal to the distal margin of the lesion). The proportion of the leg covered by GSD lesions (b) was obtained by dividing the total length of line a by the total length of line A (b = a/A); FR = front right; FL = front left; BR = back right; BL = back left.

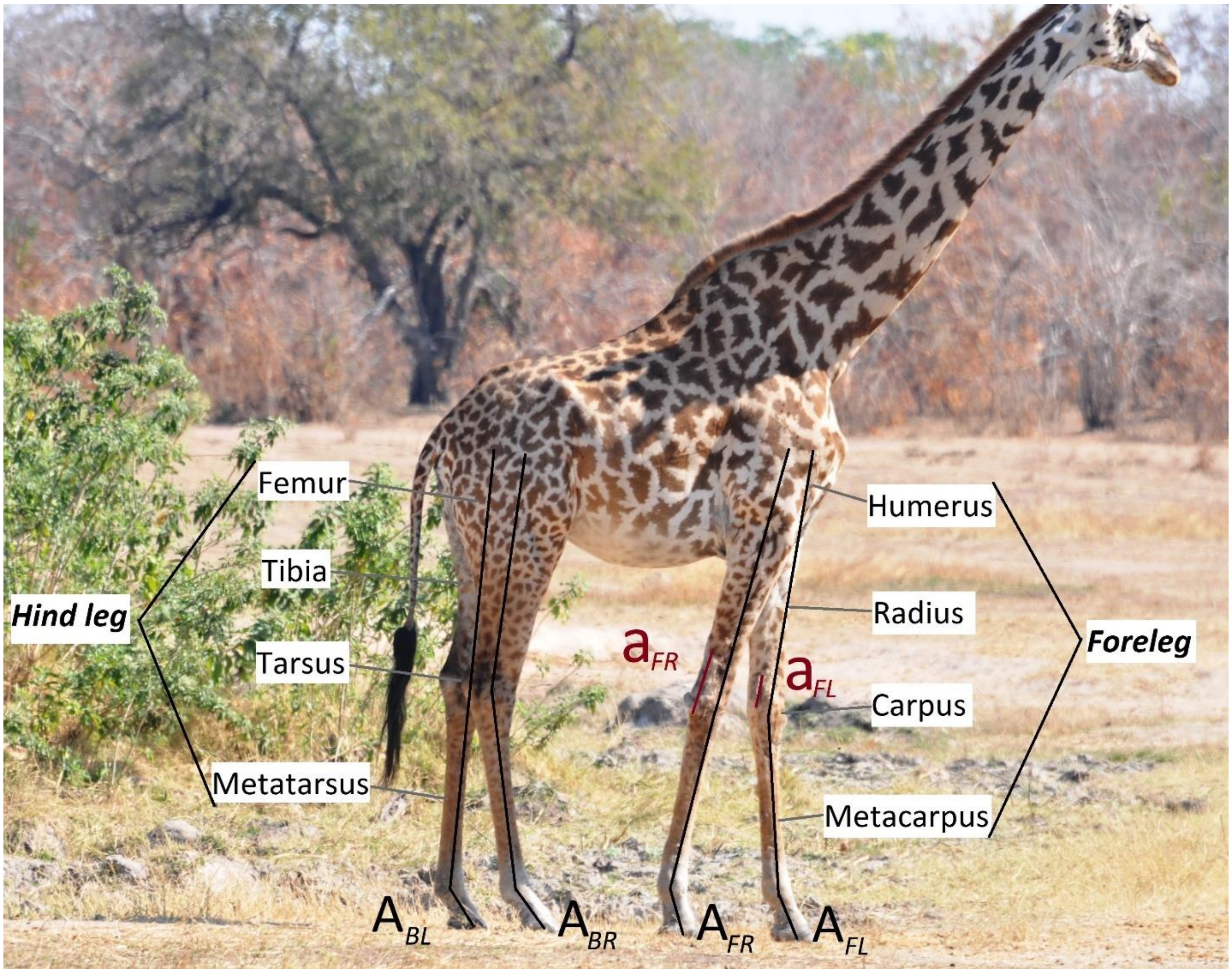


Figure 1.3.

Distribution of mild, moderate and severe GSD lesions on the legs of giraffe in Ruaha National Park (A) and Serengeti National Park (B), derived from camera trap images, and individually-recognized giraffes in Ruaha National Park, derived from road-based photographic mark-recapture surveys (C). FR = front right; FL = front left; BR = back right; BL = back left; Mi = Mild; Mo = Moderate; Sev = Severe; S = Serengeti National Park; R = Ruaha National Park (Camera trap data); Ru = Ruaha National Park (Digital camera data).

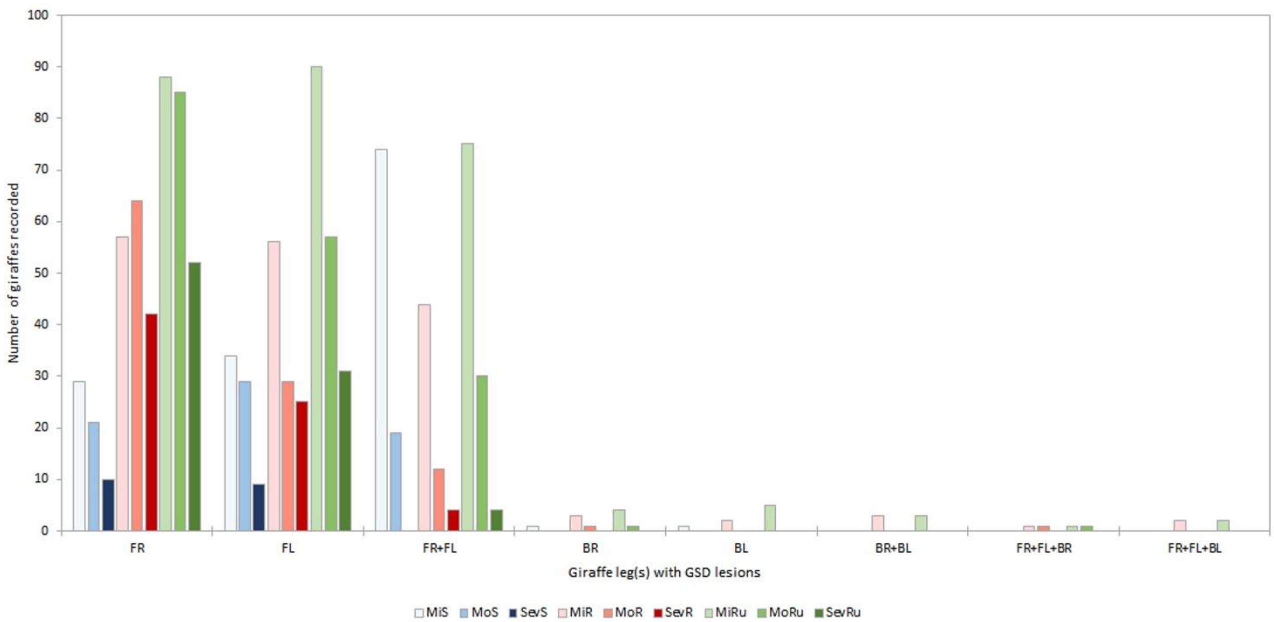


Figure 1.4.

Illustration of the three categories of GSD severity on giraffe legs in Ruaha National Park, Tanzania: mild (a: 6% of leg affected); moderate (b: 25% of leg affected) and severe (c: 47% of leg affected).

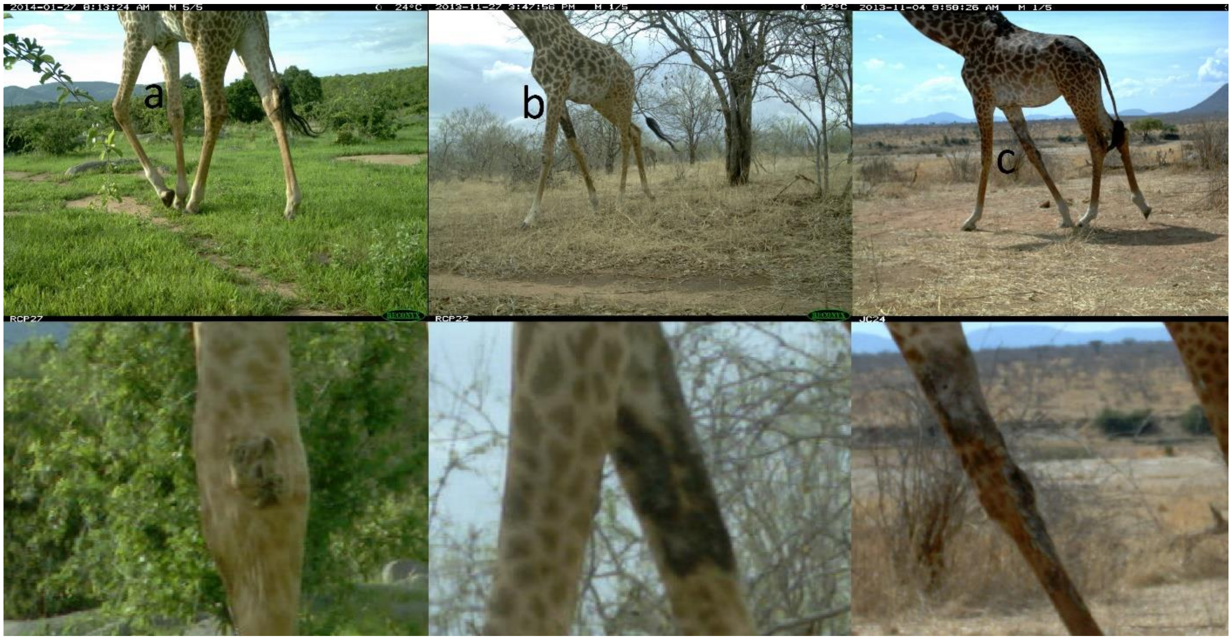
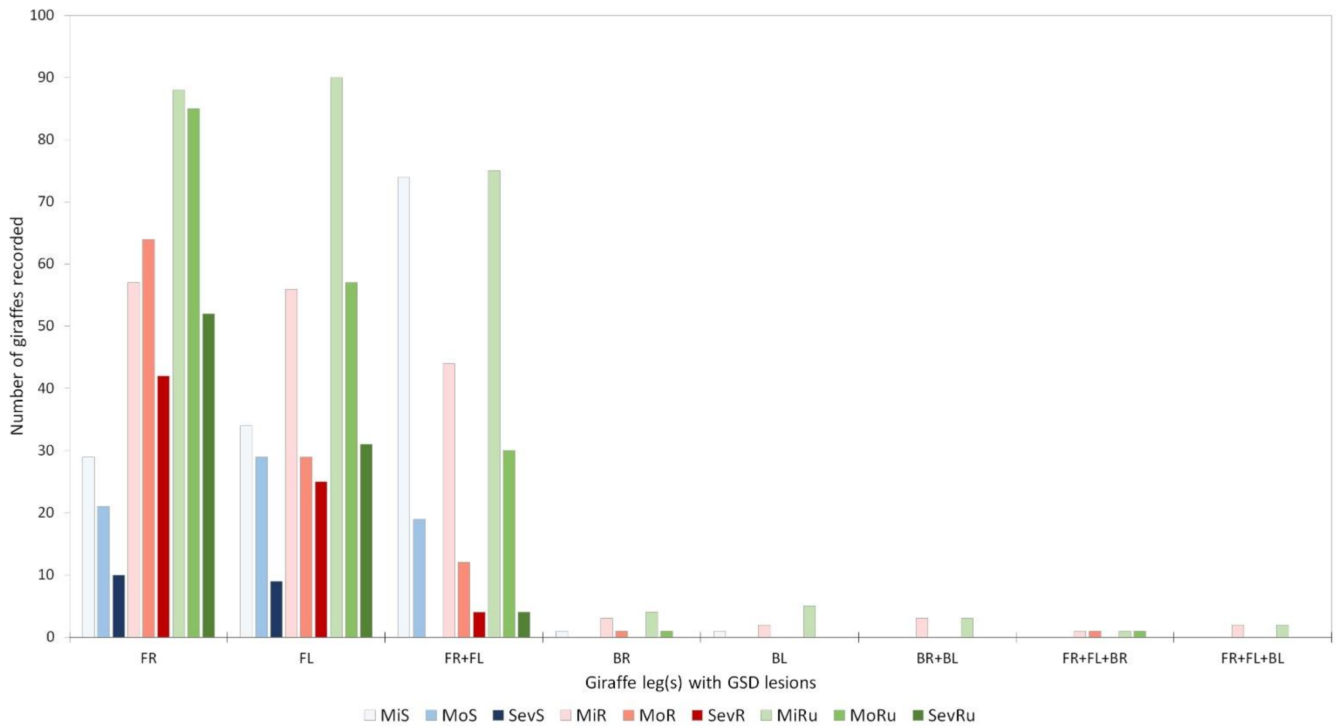


Figure 1.5.

Distribution histogram of the proportion of giraffe leg affected by GSD in Ruaha National Park and Serengeti National Park. Error bars show 95% confidence intervals. There is no statistically significant difference [$D_{n'n''}$ (0.3333) < D (0.5552)] between images from known giraffe and camera trap images of giraffe indicating distribution of GSD severity categories is similar. IR = Individually recognized; Cam = camera trap data.



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CHAPTER 2: EXPLORING THE CONNECTIONS BETWEEN GIRAFFE SKIN DISEASE AND LION PREDATION

Abstract

Rates at which predators encounter, hunt, and kill prey are influenced by, among other things, the intrinsic condition of prey. Diseases can considerably compromise body condition, potentially weakening ability of afflicted prey to avoid predation. Understanding predator-prey dynamics is particularly important when both species are threatened, as is the case with lions (*Panthera leo*) and giraffes (*Giraffa* spp.). Importantly, an emergent disease called giraffe skin disease (GSD) may affect predatory interactions of lions and giraffes. Hypotheses suggest GSD may negatively affect the likelihood of giraffes surviving lion attacks. I evaluated giraffe-lion interactions in Ruaha National Park, Tanzania, where 85% of the giraffe population has GSD. I monitored lion hunting behavior and estimated proportion of the giraffe population with GSD and evidence of 'lion marks' from assumed previous lion predation attempts (i.e. claw marks, bite marks, and missing tails). Although I recorded lions hunting and feeding on 16 different prey species, giraffes represented the largest prey category (27%; n = 171 of 641). For age and sex cohorts combined, 26% (n = 140 of 548) of encountered giraffes displayed evidence of previous lion predation attempts. Occurrence of lion marks was higher for adults and males in the giraffe population, suggesting that these individuals were more likely to survive lion attacks. I also found marginal evidence of a positive relationship between giraffes with severe GSD and occurrence of lion marks. My results identify giraffes as important prey species for lions in Ruaha National Park and suggest that GSD severity plays a minor role in likelihood of surviving a lion attack. This is the first study to explore connections between lion predation and GSD. I explore the ecological implications of disease ecology on predator-prey interactions and consider

opportunities for future research on causal links between GSD and giraffe vulnerability to lion predation.

2.1. Introduction

Interactions between carnivores and ungulates are notably complex (Mysterud, 2013; Dröge et al., 2017; Montgomery et al., 2019). Research into these dynamics has provided insights into how prey species alter their behaviours, movements, and habitat selection in relation to predation risk (Hebblewhite & Pletscher, 2002; Hebblewhite & Merrill, 2009; Vucetich et al., 2011). Characteristics of carnivore and ungulate populations, as well as the environment in which these species interact, influence the magnitude of antipredator responses (Montgomery et al., 2013; Moll et al., 2017). Ungulates, for instance, modulate selection of comparatively 'safe' habitat where the probability of encountering predators is predictably lower (Thaker et al., 2011; Montgomery et al., 2014). Ungulates also increase vigilance, although this behavior varies according to group size, age and sex, body size and condition, time of day, moon phase, and distance to woodland edge and waterhole (Winnie et al., 2006; Crosmary et al., 2012; Tambling et al., 2012; Mejlgaard et al., 2013; Creel, Schuette, & Christianson, 2014; Kuijper et al., 2014; Lashley et al., 2014).

The body size of ungulates also affects the nature of carnivore-ungulate interactions (Hayward & Kerley, 2008). Ungulates with smaller body size, for instance, are vulnerable to predation from a broader suite of sympatric large carnivores compared to larger-bodied ungulates in the prey assemblage (Sinclair, Mduma, & Brashares, 2003; Liley & Creel, 2008; Périquet et al., 2012). In African systems, carnivore predation risk of animals weighing >1,000 kg at the adult stage (e.g., giraffes - *Giraffa* spp., hippopotamus - *Hippopotamus amphibius*, rhinoceros - *Ceratotherium simum.* and *Diceros bicornis*, and elephants - *Loxodonta* spp.) is negligible

(Radloff & du Toit, 2004; Owen-Smith & Mills, 2008). However, predation of juvenile animals among these species can be considerable. African lions (*Panthera leo*) account for 58-75% of mortality of giraffe calves in dry seasons when food resources are scarce (Leuthold, 1979; Pellew, 1983). Adult giraffes, on the other hand, are more difficult to capture because they fend off attacks by kicking (Carter et al., 2013) or outrunning lions (Mitchell & Skinner, 2011). In addition, giraffes often forage in open habitats with intermediate-height shrubs and use fission-fusion herding to modulate predation risk (du Toit & Owen-Smith, 1989). This strategy is particularly common for female giraffes that move with calves in large herds offering protection from potential predators (Young & Isbell, 1991). The presence of lions does not appear to affect vigilance of adult giraffes (Cameron & du Toit, 2005; Périquet et al., 2010). Although adult male giraffes are predominantly solitary during certain periods of their life history (Ginnett & Demment, 1997; Bond et al., 2019), they are mostly able to avoid lion predation because of their large body size.

While giraffes are considered to be a preferred prey of lions (Hayward & Kerley, 2005), they generally constitute a low proportion of lion diet in systems where other prey species are concurrently available in the landscape. For instance, giraffes made up just 9.4% of lion diets in Hwange National Park, Zimbabwe, compared to buffalo (*Syncerus caffer*), which constituted 40.8% (Davidson et al., 2013), despite giraffes (1.49 individuals.km^{-2}) being more abundant than buffalo (0.92 individuals.km^{-2}) in the park (Valeix et al., 2007). In Kruger National Park, South Africa, giraffes comprised only 1.5% of lion kills, with zebras (*Equus quagga*), wildebeest (*Connochaetes taurinus*), and buffalo making up a larger portion of the lion diet (Pienaar, 1969). In Murchison Falls National Park, Uganda, lions were found to predate buffalo, Ugandan kob (*Kobus kob thomasi*), and hartebeest (*Alcelaphus buselaphus*), whereas the killing of giraffes was extremely rare (Brenneman et al., 2009). Importantly, however, certain characteristics can alter the nature of lion-giraffe interactions. For example, lions have been found to target adult giraffes that are weakened by drought and starvation (Hirst, 1969), malnutrition (Brenneman et al., 2009), young or old age (Pellew, 1983; Owen-Smith, 2008) or hunt giraffes in large prides (Wright, 1960). Emerging infectious diseases also affect predator-prey interactions (Moleón et al., 2009) including those of carnivores and ungulates (Joly & Messier, 2004). However, the extent to which diseases might modify lion-giraffe interactions remains unclear.

Giraffe Skin Disease (GSD), first recorded in Uganda in 1995, now affects giraffe populations range-wide to varying degrees (Muneza et al., 2016). The disease is characterized by lesions on the limbs, neck, shoulder, and/or chest of afflicted giraffes (Muneza et al., 2016). I hypothesized that GSD in Tanzania might influence the likelihood of surviving a lion attack given that lesions commonly appear on giraffe limbs. Anecdotal observations suggest that GSD may inhibit giraffe movements (Epaphras et al., 2012; Muneza et al., 2016), which could potentially increase vulnerability of adult giraffes to lion predation (Muneza et al., 2016).

I investigated lion-giraffe interactions in Ruaha National Park, Tanzania, which has the highest prevalence rate (86% of the giraffe population is infected) of GSD in a wild giraffe population recorded to date (Muneza et al., 2017). I surveyed the giraffe population to estimate the proportion of individuals with 'lion marks' (i.e., claw marks, bite marks, and missing tails), which I assumed indicated previous lion predation attempts, recorded presence and severity of GSD, and collected data on lion hunting behavior to document lion selection of giraffes in comparison to sympatric prey species. Importantly, lion marks provide a conservative estimate of the rates of lion attack. For instance, the marks may represent more than one attack event and there are undoubtedly instances in which lions chased giraffes and did not leave a mark. Here, I examine *i*) the role of GSD in relation to likelihood of giraffes surviving a lion attack, *ii*) discuss the implications of disease ecology for predator-prey interactions more broadly, and *iii*) explore the inferences of my research for conservation.

2.2. Methods

2.2.1. Study area

Ruaha National Park (20,226 km^2) is Tanzania's second largest national park and located in the south-central region of the country (Fig. 2.1). The park is considered a priority area for large carnivore conservation as it has important populations of cheetahs (*Acinonyx jubatus*), African wild dogs (*Lycaon pictus*), leopards (*Panthera pardus*), spotted hyaenas (*Crocuta crocuta*) and lions (Abade, Macdonald, & Dickman, 2014). Habitats in the park include open savannah, wetlands (swampy and riverine habitat), and closed woodlands (Epaphras et al., 2007). This ecosystem supports at least 13 species of ungulates that are vulnerable to lion predation (Table 2.1). The park is home to largest giraffe population in southern Tanzania with 3,881 (±1,023) individuals recorded during aerial surveys (TAWIRI, 2015).

2.2.2. Photographic capture-recapture surveys

I conducted road-based photographic encounter surveys for giraffes from May 2015 to August 2015 to quantify sex, age class (calf, subadult or adult), presence and severity of GSD, and evidence of a previous lion predation attempt. I divided the accessible road network into five transects, each ~100 km in length ($\bar{x}$ = 99.22 km, SD = 3.72; Fig. 2.1), which I then surveyed 10 times. I considered giraffes to be detectable within a 200 m buffer on either side of the transect. When I encountered giraffes, I took georeferenced right-side photos of each animal using a Nikon D300s DSLR camera with an auto-focus S-DX Nikkor 70-300mm f/3.5 – 5.6 ED VR lens to facilitate individual animal identification. Given that GSD lesions manifest externally on afflicted giraffes and can be seen clearly using binoculars (Epaphras et al., 2012), I classified severity of the lesions in four different categories: none, mild (small skin nodules of <3cm in diameter with raised hair), moderate (medium-sized patch of alopecic lesions of 10 – 16cm in diameter) and severe (large-sized lesions >16cm in diameter characterized by scabs and cracks with raw fissure; see Muneza et al., 2016). Later, I used the pattern recognition software Wild-ID (Bolger et al., 2012) to identify individual giraffes and obtain their unique capture histories (see Muneza et al., 2017).

I also examined prevalence and anatomical location of marks (claw marks, bite marks, missing tail) assumed to be indicative of a previous lion predation attempt (Fig. 2.2). When prey survives an attempted carnivore attack, marks of the predation attempt can remain visible as scars (de Azevedo, 2008), which are regularly used to study predator-prey interactions (Carpenter, 1998; Fahlke, 2012). Such marks have been effectively used to examine the influence of age, sex, herd size, and height of individually-recognized Masai giraffes (*G. c. tippelskirchi*) in Serengeti National Park, Tanzania subject to lion predation (Strauss & Packer, 2013). It is important to note that lions are the only sympatric carnivore species likely to be responsible for these distinctive marks on giraffes (Schaller, 1972; Strauss & Packer, 2013). I acknowledge, however, that my survey techniques could not distinguish between single or multiple lion predation attempts or the date of the attack(s). Thus, where these marks (hereafter referred to as lion marks) were detected, I conservatively estimated that giraffes had survived at least one previous lion predation attempt.

2.2.3. Spatial capture-recapture model

I fit a spatial capture-recapture (SCR) model to the photographic capture-recapture survey data to estimate the *i*) probability of lion marks in the giraffe population and *ii*) relationship between probability of lion marks and sex, age, and GSD severity while accounting for individual variation in capture probability. I divided the study area into 2 x 2 km grid cells and modeled the number of encounters for individual i in grid cell j as a Poisson random variable with mean encounter rate λ_{ij}. Following standard SCR models (Borchers & Efford, 2008; Royle et al., 2014), the encounter rate decreased with increasing distance d_{ij} between the latent activity center for individual i and the location of grid cell j using a half-normal function, such that:

$$\lambda_{ij} = \lambda_{0ij} \times \exp(-d_{ij}^2/2\sigma_i^2)$$

Both the baseline encounter rate, λ_{0ij} (when $d_{ij} = 0$), and the scale parameter of the half-normal detection function, σ_i, were allowed to vary according to individual attributes including 1) sex, with female as the reference category; 2) age class, with adult as the reference category; 3) an interaction of sex × age class; and 4) the presence/absence of severe GSD. I estimated these relationships by specifying linear models on the log scale for each parameter, $\log(\lambda_{0ij}) = \mathbf{X}_i\boldsymbol{\alpha}$ and $\log(\sigma_i) = \mathbf{X}_i\boldsymbol{\delta}$, where $\mathbf{X}_i$ is the design matrix of individual attributes and the parameters to estimate are $\boldsymbol{\alpha}$ and $\boldsymbol{\delta}$. In addition to the individual attributes, I included an offset term on the encounter rate to adjust for total hours (i.e., effort) spent surveying grid cell j, calculated as the total survey duration scaled by linear length of overlapping survey units. Latent activity centers were assumed to be uniformly distributed as a homogeneous point process such that density was expected to be constant across the region (Royle et al., 2014). I eliminated calves from SCR analysis because their movement directly depends on their mother, which does not meet the criteria of independence required for such models (Borchers & Fewster, 2016), thus my inferences are limited to adults and subadults.

As part of the SCR model, individual attributes were explicitly modeled to both estimate their proportions within the giraffe population and to explore relationships with the presence of lion marks. Each of the three individual attributes (sex, age class, severe GSD) were specified as binary random variables with an associated probability for the non-reference category: $\Pr(\text{male}_i) = \psi_{\text{male}}$; $\Pr(\text{subadult}_i) = \psi_{\text{subadult}}$; and $\Pr(\text{sevGSD}_i) = \psi_{\text{sevGSD.}}$ While most encountered individuals had an observed value for each attribute, some attribute observations were incomplete making them partially latent variables. Unobserved individuals have no observations by definition. These challenges were accommodated by fitting the model using a Bayesian approach with data augmentation (Royle, Dorazio, & Link, 2007) which is a common implementation for SCR (Royle et al., 2014). In this way, attribute probabilities were assigned prior distributions which combined with observed proportions among encountered individuals and any adjustments due to encounter rates to inform posterior distributions. This resulted in an observed value or estimated latent value of each attribute for each individual *i* in the model. Finally, I estimated the occurrence of lion marks with a logit-linear model:

$$\text{logit}(\psi_{\text{marks}}) = \beta_0 + \beta_1\text{male}_i + \beta_2\text{subadult}_i + \beta_3\text{sevGSD}_i$$

Here, the intercept β_0 represents the logit-scale probability of an adult female without severe GSD having evidence of a lion attack, while the other regression coefficients represent the relative change in this probability due to individual attributes.

I fit the model using Markov chain Monte Carlo (MCMC) methods in JAGS (Plummer, 2003) with the jagsUI (Kellner, 2014) package in R (R Core Team, 2019). I used vague prior distributions for all model parameters including Uniform(0, 1) for all probabilities; Uniform(–10,

10) for log-scale intercepts; and Normal(0, 10) for all other regression coefficients (Table 2.3). I fit 3 chains of 9,000 iterations after a 1,000-iteration adaptation period, leaving 27,000 values forming the posterior distribution for each parameter. Model convergence was approximated by examining trace plots and ensuring an R-hat value <1.1 for all model parameters. I report posterior mean values with standard deviations and 95% credible intervals for model parameters. I considered regression coefficients with 95% intervals that did not overlap zero as evidence for an effect. Model code was written in BUGS language.

2.2.4. Lion hunting surveys

To examine patterns of prey selection by lions, I recorded locations where lions were observed to successfully hunt prey (i.e., chase and kill) between January 2009 and December 2015. I recorded the number of individual lions detected and prey species hunted. I then used Jacobs' index to quantify relative selection of different prey species in Ruaha National Park based on:

$$D = \frac{r - p}{r + p - 2rp}$$

Whereby *r* is the proportion of a species of the total hunts and *p* is the proportional availability of the species (Jacobs, 1974). Proportional availability was obtained from data on aerial surveys conducted by the Tanzania Wildlife Research Institute (2015) and my surveys on lion feeding behaviour. Jacobs' index values for a prey species *D* range from –1 to +1 with negative values indicating avoidance and positive values indicating selection.

2.3. Results

I recorded 336 sightings (consisting of ≥ one giraffe) and collected 2,129 images of giraffes from photographic capture-recapture surveys. I detected 622 individual giraffes including 333 adult females, 160 adult males, 38 subadult females, 32 subadult males, and 59 calves. The average giraffe herd size was 5.28 (±0.16) individuals (range 1–36). I observed 21 instances of giraffes limping due to injuries likely sustained from a lion predation attempt as I recorded lion marks on these individuals (Fig. 2.2, main panel). I was able to confirm the presence or absence of lion marks among 548 giraffes in the population. Among those, 26% (n = 140) had lion marks, with female giraffes accounting for 59% (n = 82) of the individuals I encountered with signs of attempted predation. Female giraffes also exhibited a higher variation in anatomical location of lion marks (Fig. 2.3). I observed three calves (2.1%) with either a missing tail (n = 2) or claw marks on the rump and limbs (n = 1). I recorded both severe GSD and lion marks in 43 female (37%) and 36 male (28%) giraffes of the study population.

Parameter estimates from the SCR model indicated that individuals were more likely to be female (64%; ψ_{male} = 0.36 [0.030, 0.415]) and adult (87%; $\psi_{subadult}$ = 0.13 [0.094, 0.177]) giraffes, with 85% of the study population having GSD and 60% having severe cases of the disease (Table 2.3). The proportion of the giraffe population with lion marks was highest (i.e. >40%) in the northeastern section of the study area (Fig. 2.4). I found strong evidence that lion marks were more common on male giraffes (β_1 = 0.519 [0.117, 0.923]), and the probability of subadult giraffes having lion marks was considerably lower (β_2= –0.829 [–1.643, –0.078]; Table 2.2). I found marginal evidence that giraffes with severe GSD were more likely to have lion marks (β_3= 0.334 [–0.083, 0.759]). Adult males with severe GSD had the highest occurrence of lion marks (Fig. 2.5).

The average size of lion prides was 5.8 individuals (range 1 – 42), and I documented 641 unique sightings of ≥ one lion hunting 16 different prey species (Fig. 2.6). Based on these observations, giraffes were the most selected species by lion (n = 171) followed by buffalo (n = 119), elephant (n = 75), and zebra (n = 52). Giraffes accounted for 27% (n = 171 of 641) of the prey species in these lion hunts. Jacobs' index revealed that giraffes (D = 0.24) and buffalo (D = 0.23) were positively selected by lions, whereas eland (D = – 0.21) and greater kudu (D = – 0.14) were avoided.

2.4. Discussion

I examined the potential implications of GSD on the predatory interactions of lions and giraffes. The Jacob's index values revealed that giraffes, with buffaloes a close second, were the most highly selected prey species by lions in Ruaha National Park (Table 2.1), consistent with predictions based on body size (Hayward & Kerley, 2005). This relationship was evident despite the fact that other concurrent prey species were more abundant than giraffes. Additionally, across a six-year monitoring period, I found that lions hunted giraffes at a higher frequency than other sympatric prey species (Fig. 2.6), with GSD severity as a potential modulating mechanism. Apparent preference of lions for giraffes in Ruaha National Park could indicate a predatory strategy of lions targeting a large prey to access a higher concentration of food resources in a single kill (Loveridge et al., 2009). Among the prey preferred by lions in Ruaha National Park, giraffes have the largest average body mass (Table 2.1; Hayward & Kerley, 2005). This explanation might be supported by the fact that lions in Ruaha National Park tend to move in larger prides. The average size of a pride in Ruaha National Park (n = 5.8) is almost two lions higher than other parks in Tanzania (Mosser & Packer, 2009). Furthermore, the range of lion prides that I observed in Ruaha National Park was as high as 42 individuals. Thus, lions in the park could simply be targeting giraffes more often to acquire food resources for large prides or be more successful in cooperatively hunting giraffes regardless of GSD severity.

I detected spatial variation in the proportion of the giraffe population with evidence of previous lion predation attempts. Specifically, I found that the northeastern section of the study area (Serengeti Ndogo transect; Fig. 2.1) had the highest proportion of giraffes with lion marks (Fig. 2.4), though the area also had the highest density of giraffes in the park. This area is adjacent to open savannah and woodland habitat directly next to the Great Ruaha River, which provides the only year-round natural source of water for wildlife in the park used by giraffes and other prey (Mtahiko et al., 2006). I suspect that lions may be using hunting grounds near water to increase hunting success (*sensu* Funston, Mills, & Biggs, 2001; Spong, 2002). However, lion hunting behavior and giraffe availability do not alone explain why giraffes are highly selected prey for lions in Ruaha National Park. I detected a weak positive relationship between giraffes with severe GSD and the occurrence of lion marks. It is unknown whether this relationship exists in other giraffe populations where GSD has been recorded given that there is variation in manifestation of the disease across the range of giraffes (Muneza et al., 2016). As such, additional research is required to assess the impact of GSD on lion-giraffe interactions across the range of these species.

Lions have also been found to select for vulnerable characteristics in prey populations including malnourishment, disease, and life history stage (Hirst, 1969; Brenneman et al., 2009; Moleón et al., 2009). Some have speculated that the presence of severe GSD lesions on the limbs of Masai giraffes might limit their movements and subsequent ability to evade lion predation (Karimuribo et al., 2011; Epaphras et al., 2012). I detected marginal evidence of a positive relationship between giraffes with severe GSD lesions and occurrence of lion marks (Table 2.2,

Fig. 2.6), suggesting that GSD severity did not affect the likelihood of surviving a lion attack. However, I did not identify any direct links between GSD and likelihood of surviving a lion attack. The patterns that I detected are correlative rather than mechanistic. Additional research will be needed to assess whether GSD physically weakens giraffes, thereby making them easier prey of lions. I found that while male giraffes constituted ~36% of the population in the study area, they were more likely to have lion marks (odds ratio = $\exp(\beta_1)$ = 1.68 [1.12–2.52]; Table 2.2). Male giraffes are more likely to survive a lion attack (Pellew, 1983; Carter et al., 2013) whereas females and subadults with smaller body sizes (van Sittert, Skinner, & Mitchell, 2010) are less likely to survive a lion attack. Thus, as GSD appears to be a progressive disease, I suspect that adult male giraffes may be better able to survive long enough for GSD lesions to advance in severity (Muneza et al., 2016). Additional surveys in different seasons that include mortality data can help determine the direct links between the progression of GSD severity and probability of surviving lion attacks.

In discussing the patterns I observed, my hope is to spur the process of identifying creative future avenues of research regarding the nuanced roles of disease in predator-prey interactions. Lions account for ~75% of giraffe calf mortality (Pellew, 1983). I do not suspect that disease ecology is particularly influential among lion and calf/sub-adult giraffe interactions given that GSD is rare in these life history stages (Muneza et al., 2017). This contention is supported by the fact that I detected few sub-adult giraffes and calves with lion marks (Fig. 2.3), suggesting that they rarely survive lion hunts (Pellew, 1983; Strauss & Packer, 2013). Despite the general lack of GSD influence on giraffe survival, additional research may be warranted regarding potential mechanistic connections. It remains unclear, for instance, whether GSD directly influences survivability of giraffes or if vulnerability to lion predation might increase for individual giraffes with this disease. Furthermore, I observed 21 giraffes with both severe GSD and evidence of a previous lion predation attempt moving with difficulty during my surveys. From my observations, the lion marks heal but severity of GSD does not change (Muneza et al., 2017). I identified one limping giraffe with a lion predation mark on the front left limb in June 2015 and later encountered that same individual in August 2015 with what appeared to be a healed lion predation wound (Fig. 2.7). In contrast, the GSD lesions were still visible and had the same category of severity. Given that recent studies have focused on external manifestation of GSD (Mpanduji, Karimuribo, & Epaphras, 2011; Muneza et al., 2016, 2019), there is a critical need to expound on the pathophysiology of GSD.

My study shows that GSD may not have a direct impact on lion-giraffe interactions. Additional investigation into GSD-induced behaviours of and physiological changes in giraffes may elucidate any potential variations in these interactions. Research has shown that diseases influence predator-prey interactions (Joly & Messier, 2004; Moleón, Almaraz, & Sánchez-Zapata, 2008) and in some instances can lead to collapse of entire populations either directly or indirectly (Jones et al., 2007; Puechmaille et al., 2011). This is particularly important given that little is known about the indirect effects of diseases on populations such as changes in demographic structures (Lachish, McCallum, & Jones, 2009) or variation in vulnerability to predation. Understanding these dynamics can improve and inform wildlife management decisions and policy. In conclusion, I recommend additional research that seeks to find the mechanistic connections that may underpin correlations between GSD and lion predation in different ecosystems.

Acknowledgements

My thanks to the Ruaha Carnivore Project for the incredible support and participation in data collection. I extend my gratitude to the Leiden Conservation Foundation and Giraffe Conservation Foundation for their support of this research. Finally, I also recognize the assistance provided by COSTECH, TANAPA and TAWIRI officials in making this research possible. The views or opinions expressed herein are those of the authors and do not necessarily reflect those of NOAA, the Department of Commerce, or any other institution. I sincerely thank the anonymous reviewers who provided comment to my manuscript and as a result improved the clarity.

APPENDIX

APPENDIX

Table 2.1. Common ungulates found in Ruaha National Park and associated population estimate, Jacobs' index, average body mass, and lion (*Panthera leo*) dietary preference. Population estimates are based on data gathered by the Tanzania Wildlife Research Institute (2015), whereas lion dietary preference was adapted from Hayward & Kerley (2005). I calculated Jacobs' index for species where both lion hunting and population estimates were available.

Common name	Scientific name	Population estimate *n*	Jacob's index *D*	Average adult body mass (kg)	Lion dietary preference
Buffalo	*Syncerus caffer*	29,211	0.23	481	Preferred
Duiker	*Sylvicapra grimmia*	12,187	-	25	Avoided
Eland	*Taurotragus oryx*	2,135	-0.21	400	Taken in accordance to relative abundance
Elephant	*Loxodonta africanus*	15,836	0.13	1600	Avoided
Greater kudu	*Tragelaphus strepsiceros*	2,266	-0.14	270	Taken in accordance to relative abundance
Hartebeest	*Alcelaphus buselaphus*	3,323	-	150	Taken in accordance to relative abundance
Impala	*Aepyceros melampus*	16,087	0.02	56	Avoided
Masai giraffe	*Giraffa tippelskirchi*	3,881	0.24	900	Preferred
Reedbuck	*Redunca arundinum*	2,623	-	61	Avoided
Roan antelope	*Hippotragus equinus*	2,338	-	280	Taken in accordance to relative abundance
Sable antelope	*Hippotragus niger*	3,896	-	235	Taken in accordance to relative abundance
Warthog	*Phacochoerus africanus*	3,940	-0.12	83	Taken in accordance to relative abundance
Zebra	*Equus quagga*	4,937	0.02	271	Preferred

Table 2.2. Parameter estimates from the lion (*Panthera leo*) marks probability component of the spatial capture–recapture (SCR) model estimating the Masai giraffe (*Giraffa tippelskirchi*) population in Ruaha National Park, Tanzania, in 2015. Values are on the logit scale for the posterior distributions.

Parameter	Effect	Mean	SD	Lower 95%	Upper 95%
β_0		–1.372	0.192	–1.752	–1.011
β_1	male	0.519	0.206	0.117	0.923
β_2	subadult	–0.829	0.398	–1.643	–0.078
β_3	GSD=severe	0.334	0.216	–0.083	0.759

Table 2.3. Parameter estimates from the spatial capture–recapture (SCR) model of Masai giraffes (*Giraffa tippelskirchi*) in Ruaha National Park, Tanzania, in 2015. The individual attribute probabilities are on the probability scale, while other parameters (e.g., α, δ, β) are on the log scale. These parameters include probabilities for individual attributes such as population membership (ψ), sex (ψ_{male}), age class (ψ_{subad}), signs of GSD (ψ_{GSD}) and number of legs with severe lesions (φ_k); loglinear regression coefficients for the encounter rate (α) and the scale parameters of the half-normal detection functions (δ and β); and derived parameters of population size (N).

Parameter	Effect	Mean	SD	Lower 95%	Upper 95%
ψ		0.740	0.044	0.659	0.832
ψ_{male}		0.356	0.030	0.300	0.415
$\psi_{subadult}$		0.131	0.021	0.094	0.177
ψ_{GSD}		0.852	0.015	0.821	0.880
ψ_{sevGSD}		0.596	0.030	0.535	0.655
α_0		–1.580	0.149	–1.883	–1.298
α_1	male	–0.479	0.199	–0.878	–0.097
α_2	subadult	0.319	0.323	–0.335	0.939
α_3	male|subadult	–0.516	0.457	–1.403	0.402
α_4	GSD=severe	–0.223	0.174	–0.566	0.128
δ_0		0.897	0.065	0.774	1.027
δ_1	male	0.134	0.088	–0.031	0.312
δ_2	subadult	–0.298	0.139	–0.556	–0.007
δ_3	male|subadult	0.555	0.206	0.140	0.950
δ_4	GSD=severe	–0.008	0.076	–0.161	0.136
β_0		–1.372	0.192	–1.752	–1.011
β_1	male	0.519	0.206	0.117	0.923
β_2	subadult	–0.829	0.398	–1.643	–0.078
β_3	GSD=severe	0.334	0.216	–0.083	0.759
N		1749	102	1565	1964

Figure 2.1.

The study area in Ruaha National Park, Tanzania surveyed for Masai giraffe (*Giraffa tippelskirchi*) distribution and lion (*Panthera leo*) activity (May to August 2015). The different lion sightings depict instances where lions were either hunting or feeding on giraffe.

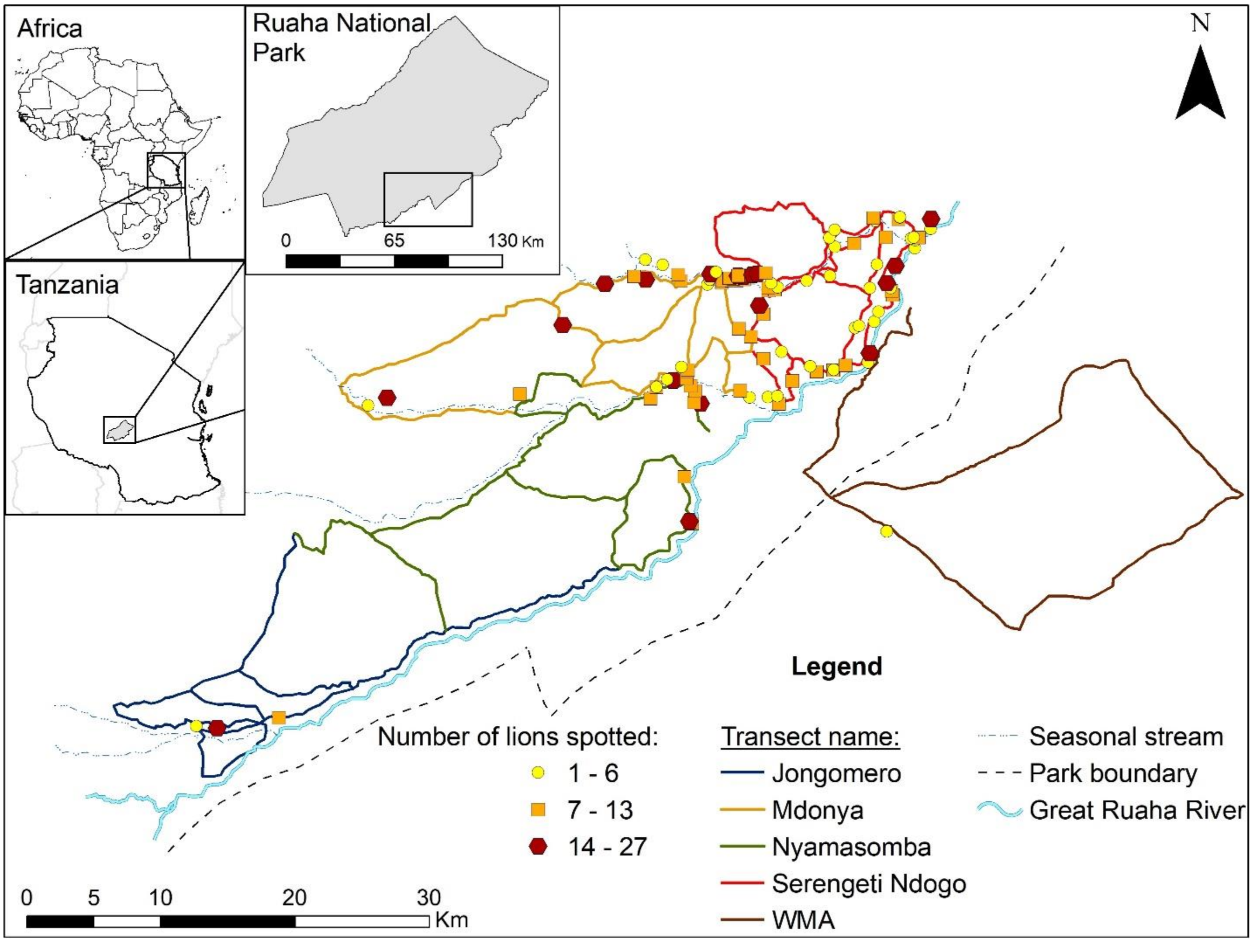


Figure 2.2.

Examples of previous lion (*Panthera leo*) predation attempts (a = claw marks; b = missing/partially amputated tail; c = bite marks) and manifestation of giraffe skin disease (GSD) on the limbs of Masai giraffe (*Giraffa tippelskirchi*) (d) that I recorded in Ruaha National Park, Tanzania (May to August 2015).

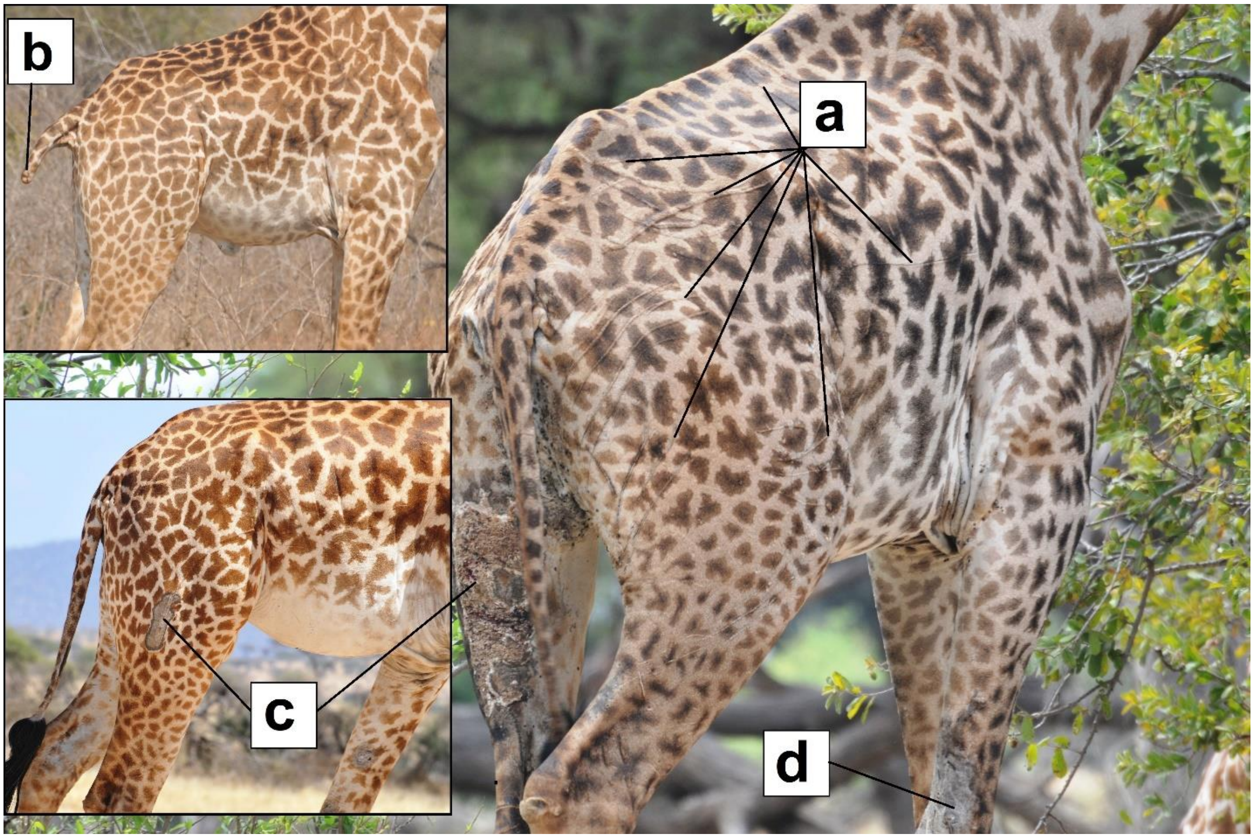


Figure 2.3.

Proportion of Masai giraffe (*Giraffa tippelskirchi*) population with evidence of previous lion (*Panthera leo*) predation attempts. The graph is based on giraffes, by age and sex, that were encountered and individually identified during the road-based photographic capture-recapture (SCR) surveys in Ruaha National Park and showed signs of attempted predation by lions (n=143). (F = female; M = male; sbA = sub-adult).

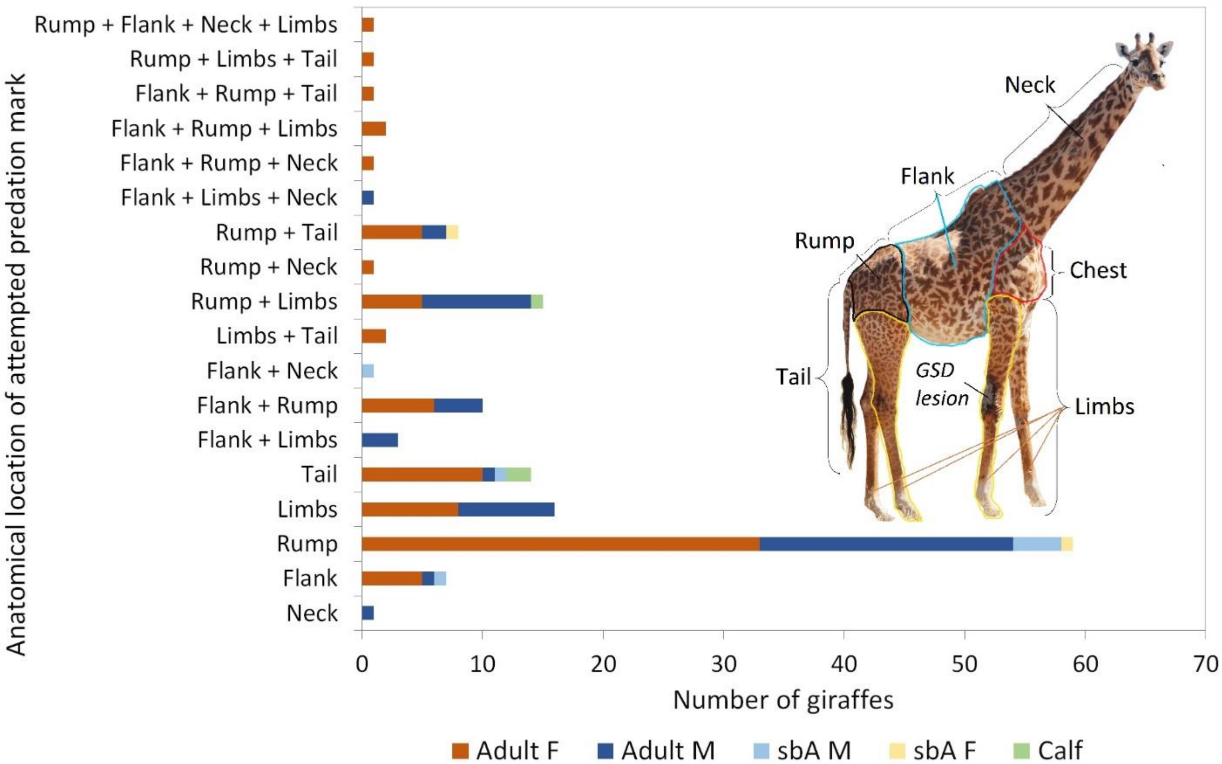


Figure 2.4.

The predictive map of Masai giraffe (*Giraffa tippelskirchi*) density and proportion of the giraffe population with lion marks in Ruaha National Park, Tanzania developed using spatial capture-recapture (SCR) models. The grid cell resolution was 2km x 2km and the map shows areas of higher giraffe survivability from lion attacks.

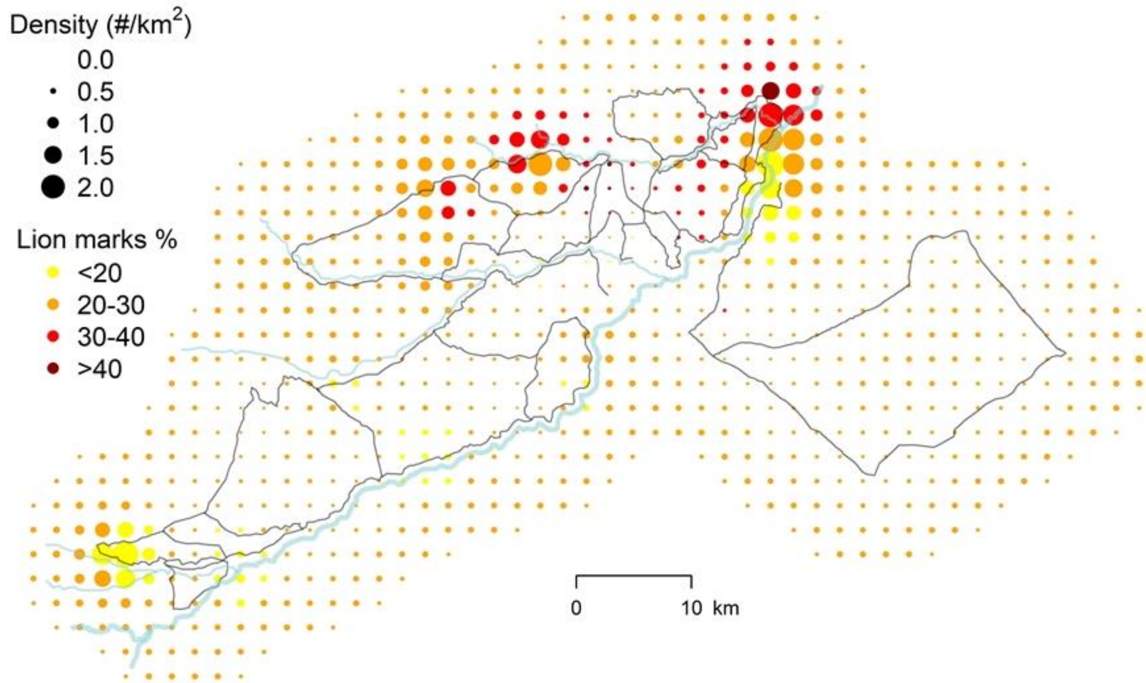


Figure 2.5.

Probability estimates of Masai giraffe (*Giraffa tippelskirchi*) with external manifestations of severe and non-severe GSD having lion marks in Ruaha National Park, Tanzania.

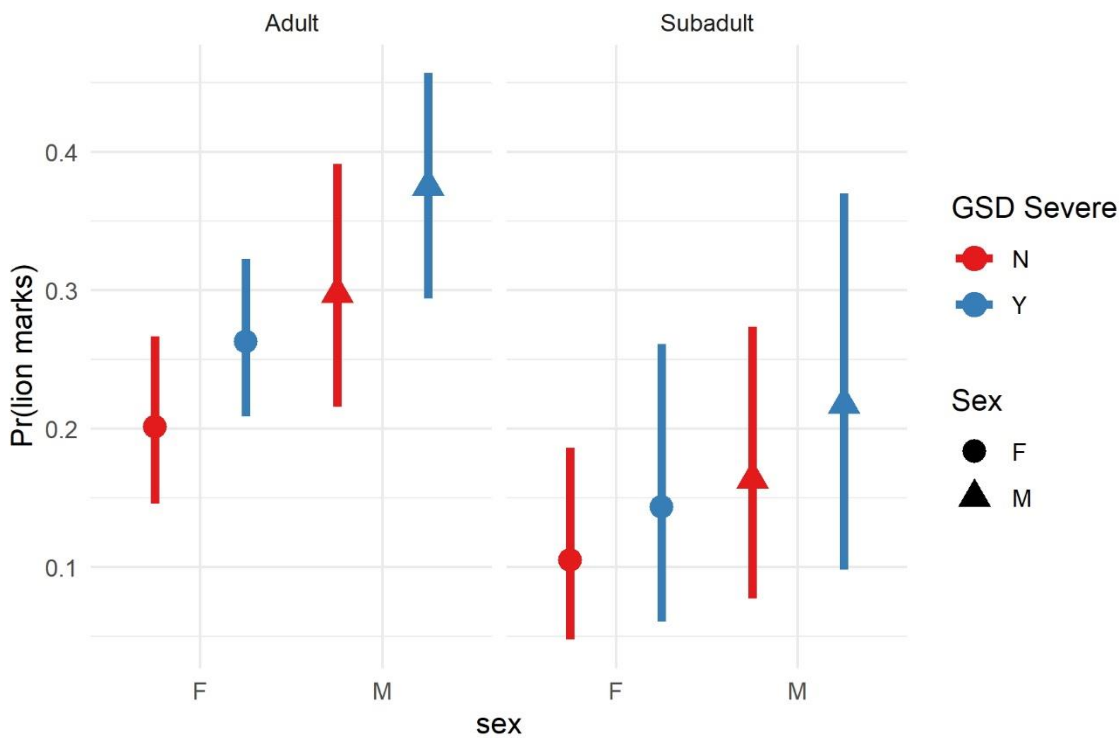


Figure 2.6.

The diversity of prey species that lions (*Panthera leo*) were observed consuming in Ruaha National Park, Tanzania. For this study, the cause of prey species mortality was not identified. The number of these interactions observed during the study (feeding and hunting/chasing) are displayed on the secondary y-axis.

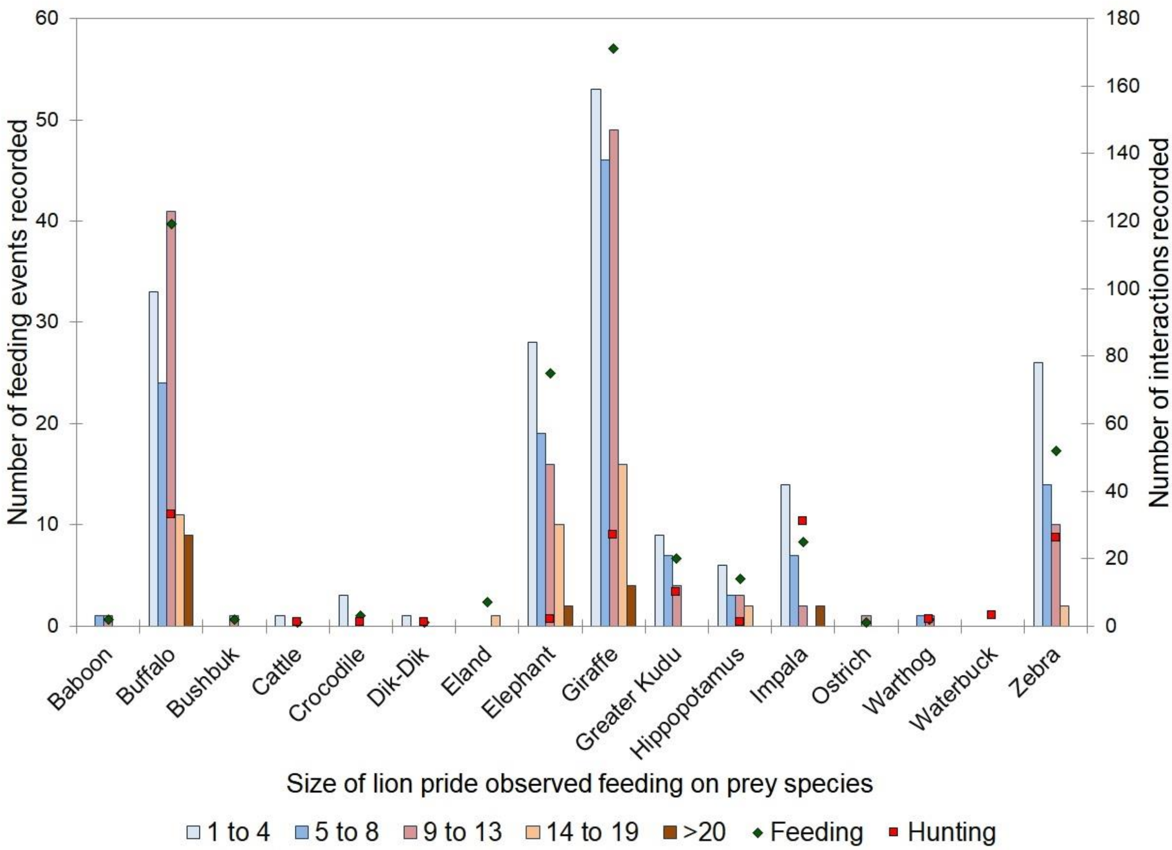
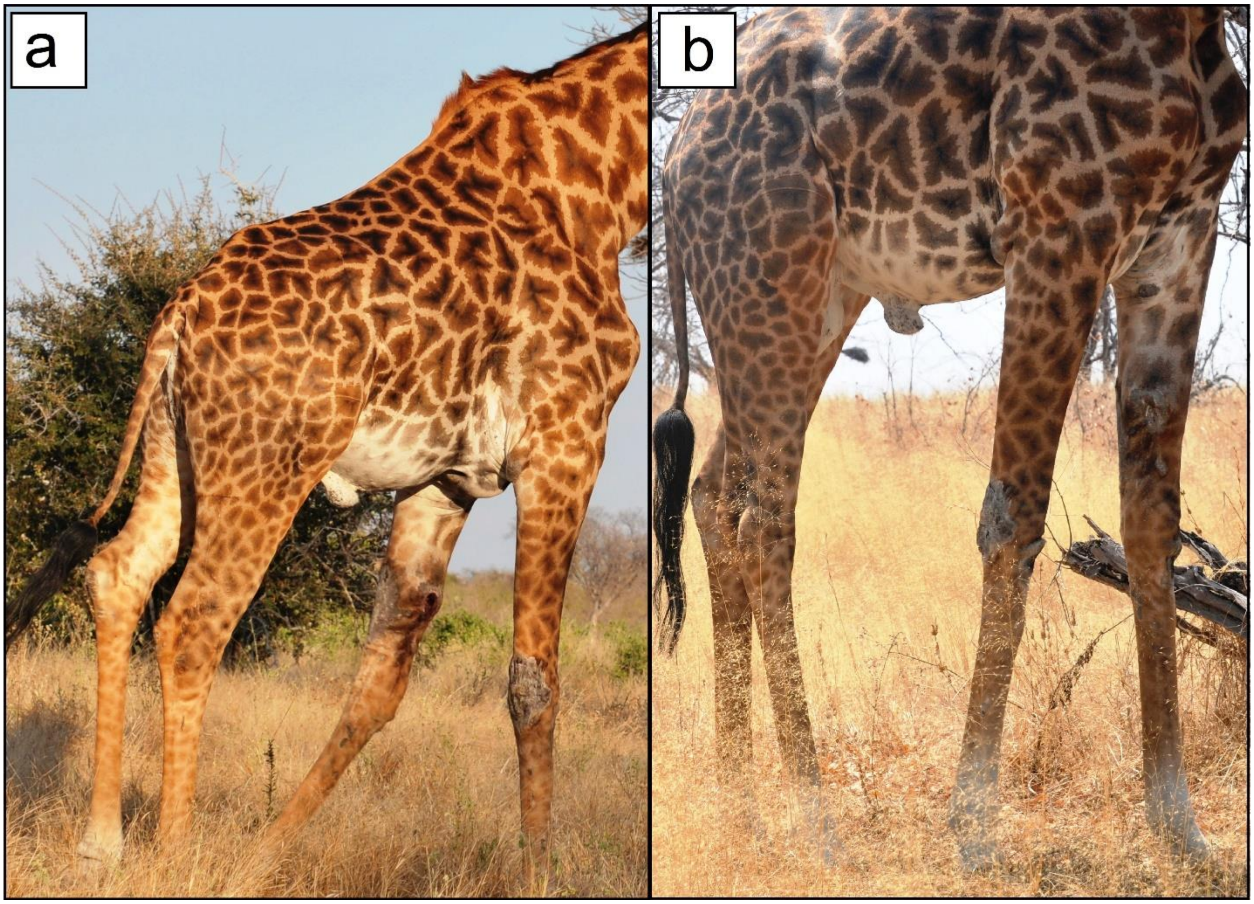


Figure 2.7.

Lion predation mark on the front left limb of a male Masai giraffe (*Giraffa tippelskirchi*) in Ruaha National Park, Tanzania. While the wound slowly recovered with time, externally at the very least (photo ‘a’ was taken a month apart from photo ‘b’), the giraffe still had a noticeable limp when moving around and the lion marks on the hind limbs and flank were still visible.



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CHAPTER 3: SOCIOECONOMIC FACTORS CORRELATING WITH ILLEGAL USE OF GIRAFFE BODY PARTS

Abstract

Unsustainable hunting, both illegal and legal, has led to local extirpation of many species globally. In the last 35 years, giraffe (*Giraffa* spp.) populations have precipitously declined with local extinctions documented in seven sub-Saharan countries. Among the reasons for these population declines, illegal hunting, commonly referred to as poaching, is believed to play an important role in some areas. Poaching of giraffe body parts is predominately motivated by consumptive, medicative, and trophy forms. However, the human socioeconomic factors that correlate with the use of giraffe parts are not well-understood. I positioned my study in the Tsavo Conservation Area in southern Kenya, which experiences comparatively high levels of poaching in the country. I used semi-structured surveys among 331 households to determine the socioeconomic factors relating to the use of giraffe parts. I documented how giraffe body parts are typically acquired and the intended use (i.e., trophy, medicative, or consumptive). I used logistic regression models to assess correlations between nine socioeconomic factors and use of giraffe parts. I found that giraffe body parts mostly had consumptive (71%; n = 184 of 259) and trophy (26.6%; n = 69) uses. One-time suppliers (35.8%; n = 87 of 243), opportunistic access (30.5%; n = 74), and widely-known markets (16%; n = 39) were the most common means of acquiring giraffe parts. Results from my models showed that three variables, gender (males), occupation (tourism worker), and land ownership were significantly ($\alpha < 0.05$ level) and positively correlated with use of giraffe parts. I describe the complex links between socioeconomic factors and use of giraffe parts and highlight the importance of implementing mitigation measures adapted to local contexts of a global challenge that many species of conservation concern are facing.

3.1. Introduction

Humans use animal parts for a variety of reasons including food, clothing, trophies, traditional medicine, luxury goods, and as integral parts of various cultural rituals (Brashares et al. 2004; Negi and Palyal 2007; Zhang et al. 2008; Simon 2019; Jugli et al. 2020). Due to both local and global demand for these animal parts, many species have been intensively trafficked, hunted, and traded legally and illegally (Willcox and Nambu 2007; Scheffers et al. 2019). Unsustainable harvest pressure has, in many instances, led to local extirpation of animal populations (Lyons and Natusch 2011; Prowse et al. 2013). Illegal hunting, commonly referred to as poaching, is an important source of harvest pressure that occurs around the world (Knapp 2012; Kahler et al. 2013; Montgomery and Macdonald 2020). Three predominant motivations for poaching are recognized, including trophy (acquisition of animal parts for decorations, trade, rituals or luxury goods), medicative (incorporation of wildlife in traditional remedies, aphrodisiacs or health supplements), and consumptive (use of wildlife as primary or secondary source of protein; Montgomery, 2020). Given variation of intended use of animal parts linked to these types motivations for poaching, there are a diversity of uses (e.g., human needs, financial incentives) among people that choose to poach (Persha et al. 2010; Duffy et al. 2016; Knapp et al. 2017; Lunstrum and Givá 2020). For instance, poachers may target animals to meet their basic human needs for non-commercial purposes, whereby personal wellbeing and survival are the primary drivers (Kahler and Gore 2012; Lindsey et al. 2013). In other instances, poachers may primarily seek financial incentives and traffic animal parts through black markets (Grey-Ross et al. 2010; Knapp et al. 2017; Lunstrum and Givá 2020). Therefore, the different uses of animal parts from poached animals likely have complex correlations with socioeconomic characteristics of the participants (Knapp 2012; Kurland et al. 2017; Montgomery 2020).

Due to prevailing biophysical characteristics that generate and maintain biodiversity, the Global South tends to be where the majority of the world's flora and fauna remain (Andelman and Willig 2003; Collen et al. 2008; Challender and MacMillan 2014). At the same time, many regions in the Global South are undergoing rapid human population growth and infrastructure development (Luck 2007; Kummu and Varis 2011). As such, poaching of wildlife is an important conservation problem in the Global South (Warchol 2004; Scheffers et al. 2019). For instance, consumptive poaching and trade of animal parts are common in rural households in many parts of sub-Saharan Africa, especially among communities living adjacent to protected areas (Fa and Brown 2009; van Velden et al. 2018; Gaodirelwe et al. 2020). Ungulates are often targeted by poachers because they provide an important food source for small-scale agricultural landholders, particularly during times of crop loss (Wilfred and Maccoll 2015). Poachers may also pursue parts from high value animal species that are traded either as trophies or for their purported medical properties. Rhinos (*Ceratotherium simum* and *Diceros bicornis*), for example, are poached for their horns, which are incorporated in traditional medicines, often in East Asian markets, and can reach prices of USD60,000 per kg (Hübschle 2016; Cheung et al. 2018; Dang Vu and Nielsen 2018). Skins, claws, and teeth of large carnivores are predominantly used as trophies, curios, or regalia when incorporated in traditional dress (Williams et al. 2017; Naude et al. 2020). Ivory, most often obtained from tusks of certain species, is used to make ornaments and objects that, at least historically, have connoted high social status (Stiles 2004; Gao and Clark 2014). Clearly, animals are pursued for different body parts for a diversity of uses (Becker et al. 2013; Annecke and Masubelele 2016; Lunstrum 2017; Hauenstein et al. 2019; Schlossberg et al. 2020). Species targeted by poachers, in part resulting from that pressure, are often wildlife species of conservation importance. Still, there are other charismatic and high-value species in the Global South, giraffes (*Giraffa* spp.) for instance, that are facing severe pressure from poaching but their conservation status remains largely uncertain to the public and scientific community (Courchamp et al. 2018; Dunn et al. 2021).

Giraffes historically occupied habitats both within and outside of protected areas (O'Connor et al. 2019). Given range contractions however, there are currently more giraffe populations occurring in private and community-owned conservancies than there are in government-managed protected areas, especially in East Africa (Okello et al. 2015; Ogutu et al. 2016; O'Connor et al. 2019). Among these matrices of villages and conservation areas, giraffes often compete with livestock for rangeland access (Jayne et al. 2014; O'Connor et al. 2015; Greiner 2017). The growth and expansion of human populations and settlements in East Africa also coincided with increasing human-wildlife interactions, placing considerable pressure on wildlife (Butt and Turner 2012; Kimiti et al. 2016; Ogutu et al. 2016; Okello et al. 2016; Masiaine et al. 2020). In the last 35 years, giraffe populations have gone extinct in seven countries (Muller et al. 2018), with rates of decline highest in East and Central Africa (Muneza et al. 2018; Bolger et al. 2019; O'Connor et al. 2019). The extent to which poaching might have influenced this decrease remains largely unquantified.

Giraffes may be unique as taxa for which their body parts are used for trophy, medicative, and/or consumptive purposes. Giraffe skin, for example, is a prized trophy that is preferred for use as water or milk carriers because the skin of other animals is believed to bring bad luck (Muneza et al. 2018). Poachers also seek out giraffes solely for their tail, which is used as dowry in traditional marriages because it connotes high social status (Hall 2016). Other communities believe that some giraffe parts have medicinal properties. Giraffe bone marrow, skulls, bones, and organs are incorporated into traditional remedies for HIV/AIDS (Arusha

Times 2004; Nkwame 2007; Strauss et al. 2015). Poaching of giraffes for consumption is more widespread and considered to be a major threat to their survival (Muller et al. 2018). For example, giraffe meat is often sold among butcheries in Kenya, disguised as livestock meat, facilitating pathways for individuals to purchase illegal bushmeat either purposely or unwittingly (Ouso et al. 2020). Giraffe liver and bone marrow are incorporated into soups which are thought to increase the potential of the consumer to tolerate alcohol (Cunnison 1958). Consequently, giraffes present an interesting case study because their body parts can be harvested for trophies, consumed as food, or incorporated into traditional medicines. Given that poaching of giraffes is recognized as a threat across their range (Strauss et al. 2015; Muller et al. 2018), it is important to document the socioeconomic factors correlating with the use of giraffe body parts.

Here, I examined correlations between human socioeconomic factors and use of giraffe body parts in southern Kenya, which is an important stronghold for Masai giraffe (*G. c. tippelskirchi*) populations and an area that experiences comparatively high levels of human-wildlife conflict and poaching (Wato et al. 2006; Ogutu et al. 2016; Mukeka et al. 2018, 2020). I surveyed households set in a matrix of village lands and conservation areas to assess whether the use of giraffe body parts correlates with specific socioeconomic factors in the human population. Specifically, I collected information on whether residents in a household have obtained giraffe meat or parts, namely bone, skin, tail, skull, bone marrow, and tail hair and their intended use. Evaluating the socioeconomic factors associated with the use of wildlife parts is vital for mitigation efforts including community outreach and management responses (Child et al. 2012; Holechek et al. 2017). I discuss the implications of this research for wildlife conservation in coupled human and natural systems and detail the complex nature of poaching and trade of a species of conservation concern.

3.2. Methods

3.2.1. Study area

I positioned this study in Tsavo Conservation Area, covering approximately 60,000 km^2 in south-eastern Kenya (Fig. 1). This landscape includes a matrix of village lands situated among two of Kenya's oldest and largest national parks, Tsavo East and Tsavo West (Fig. 1). The primary vegetation types are mixed woodlands and open savannahs. Average temperatures range between 18.9°C and 32°C, and annual rainfall in the study area varies from ~300mm to 1,200mm, giving rise to a number of seasonal rivers that supply water to neighbouring communities (Oremo et al. 2019). The Tsavo Conservation Area is one of Africa's critical landscapes for a number of large mammals including large carnivores (Henschel et al. 2020) such as lions (*Panthera leo*), leopards (*P. pardus*), spotted hyenas (*Crocuta crocuta*), cheetahs (*Acinonyx jubatus*), and African wild dogs (*Lycaon pictus*). Approximately 40% of Kenya's African bush elephants (*Loxodonta africana*) are found in the Tsavo Conservation Area, which also hosts large numbers of ungulates (Lamprey et al. 2020) such as buffalo (*Syncerus caffer*), zebra (*Equus quagga*), eland (*Taurotragus oryx*), oryx (*Oryx beisa*), both Grant's (*Nanger granti*) and Thompson's (*Eudorcas thomsonii*) gazelles, gerenuk (*Litocranius walleri*), hartebeest (*Alcelaphus buselaphus*) and impala (*Aepyceros melampus*). Voi is the largest town in the Tsavo Conservation Area with a population of ~110,000 people across approximately 32,000 households (Kenya National Bureau of Statistics 2019). Hunting of wildlife has been illegal in Kenya since 1977 and perpetrators are considered poachers subject to prosecution under the Wildlife Conservation and Management Act of 2013. The Wildlife Conservation Management Act of 2013 recognizes different forms of poaching and associated penalties. A person convicted of hunting wildlife for subsistence is subject to a fine of > KES 30,000 (~ USD 300) or imprisonment for a term > six months, whereas consumptive poachers caught with bushmeat for trade are fined > KES 200,000 (~ USD 2,000) or imprisonment for a term > one year (Kenya Wildlife Service 2016). In contrast, a person that engages in trophy or medicative poaching may face severe penalties including monetary fines ranging from one million to 20 million KES (~USD 10,000 to USD 200,000), or an imprisonment term ranging from two years to life depending on conservation status of the wildlife species listed in the Wildlife Conservation Management Act of 2013 (Kenya Wildlife Service 2016). Hunting threatened or endangered animals, such as giraffes, leads to the most severe punishments (USD 200,000 and life imprisonment), and in all cases highlighted above, both the monetary and prison fines may be applied concurrently (Kenya Wildlife Service 2016). Lastly, Kenya has implemented a shoot-to-kill policy for anti-poaching patrols that encounter poachers in protected areas, which has been in effect since 1989 (Asaka 2018).

3.2.2. Household surveys

To assess the socioeconomic factors that correlate with use of giraffe body parts, I conducted semi-structured household surveys between June and July 2019 in six villages within the Tsavo Conservation Area (Fig. 3.1). I selected these villages because they participate in the Kasigau Corridor REDD+ (Reducing Emissions from Deforestation and forest Degradation in developing countries) project, which promotes coexistence of wildlife and humans for social improvement. When assessing illegal behaviors, such as use of animal parts, it is vital to gain the trust of respondents and make clear that they would not be subject to criminal penalty from the information they provided (Newing et al. 2011; Travers et al. 2019). In building relationships of trust, I trained 10 research assistants drawn from local communities that were fluent in the native languages and had a high familiarity with the study area, in that they had already participated in the local REDD+ project to conduct household surveys and record human-wildlife conflict. Participation of individuals from the survey population in data collection is a technique used to reliably acquire truthful documentation of illegal activities (see Vaske, 2008). I randomly chose households in the participating villages at the start of each day and arbitrarily selected a house every two kilometres. The distance was measured using a Garmin e-trex 30 GPS unit, along common tracks used by residents. Before each interview, I described the objective of my research, explained that there would be no criminal penalties resulting from the information provided, and presented a consent form to the respondent to participate in the study. I explicitly explained that: *i*) the interview could be terminated at any time of the respondent's choosing, *ii*) no data would be collected that could possibly be used to identify the respondent, and *iii*) anonymity would be maintained throughout the course of the study. Consent was given verbally by the respondents and recorded in writing by the questioner at the start of each interview. All survey techniques were reviewed and approved by the Michigan State University Institutional Review Board (study id 00001610) and the National Commission for Science and Technology of Kenya (permit number NACOSTI/P/20/5611).

I designed the semi-structured survey to determine which socioeconomic factors influence the use of giraffe body parts to evaluate how the parts were acquired. I asked the respondents whether any resident in the household previously used giraffe meat, skin, bone, bone marrow, hair, tail, skull, or any other part not included in the survey. I then selected six categories to describe the means by which the respondent accessed the giraffe body parts including: widely-known market-areas (i.e. established shops or commercial areas), widely-known suppliers (i.e. well-known individual without an established area of trade), one-time suppliers (i.e. a transaction that occurred only once), self, opportunistic, or other. I did not ask respondents to name the market areas nor the suppliers to maintain anonymity. In this study, opportunistic access to giraffe body parts was typified by instances where an animal either died of natural causes (drought, fatal injury, carcass left behind by predators), was culled by wildlife authorities, or died from a car or train collision, and as such was not a commercially driven transaction. The option of 'self' referred to instances where the respondent set out to hunt giraffes specifically, whereas 'other' applied to cases that were not listed in my survey. Poaching is often linked to particular socioeconomic factors such as income and ownership conditions (Kühl et al. 2009; Nieman et al. 2019). Therefore, I collected data on explanatory variables (see Table 1) including whether anyone in the household owned land (land) and the type of ownership system of the land (land_type), main income generating activity in the household (occupation), evident changes in the annual income (Income_change) of the household compared to previous years, and area of birth of the head of the household (origin). I also recorded the number of minors (under_18) and adults (over_18) to assess the size of the household. Finally, among those respondents that identified that they had used giraffe body parts but no longer do so, I asked why they made this choice. My interest here was to explore whether price, government laws, community rules, affordability of tools, availability of giraffes, and/or any other factor played a role in this decision.

3.2.3. Data analysis

To determine the socioeconomic factors that correlate with the use of giraffe body parts, I reported and grouped the parts into consumptive (meat, bone, bone marrow, tail), trophy (bone, tail, tail hair, skin, skull) or medicative (meat, bone, bone marrow, skull) categories. I then assessed the number of times respondents used giraffe body parts throughout their lifetime and for what purpose (Table 3.1). I selected these categories because law violations are sometimes considered a learned behaviour, and as such, the practice typically includes techniques of committing the violation, specific rationalizations, and understanding of conditions favourable to lawbreaking (Eliason 1999). I then fit logistic regression models in R v4.0.3 (R Core Team 2020) in package *brant* (Brant 1990). I checked for collinearity among predictor variables in package *rms* using variance inflation factors, and sequentially excluded variables with inflation factors > 5 (Harrell 2016). First, I used a logistic regression model to examine the relationship between gender, occupation, area of birth of respondent, income change, land ownership, type of land ownership, level of education, and composition of household (Table 3.1) and use of giraffe parts (i.e., yes = 1 and no = 0). I then used an ordinal logistic regression model to predict the number of times a household used giraffe parts as a cumulative link function of the nine socioeconomic factors (Table 3.1). I implemented a stepwise elimination approach for model selection. Specifically, I used a cutoff of $p < 0.1$ to select the best model as well as interpret model results for statistical significance.

3.3. Results

I completed 331 interviews across 350 households among six villages in Tsavo Conservation Area. More than half of the respondents were female (53.2%; $n = 176$) and 46.8% ($n = 155$) of the respondents were male. The average size of a household was 7.1 (range 1 – 37) and 72.5% ($n = 240$) of the respondents identified that they were born within the study area. More than half of the respondents owned land in the study area (68.6%, $n = 227$). Among the individuals that owned land, 86.3% ($n = 196$ of 227) inherited land through family members, 11.1% ($n = 25$) possessed land through a community conservancy or ranch system, and 2.6% ($n = 6$) of the respondents declined to respond. Almost half of the respondents (48.3%; $n = 160$ of 331) identified crop farming to be their primary source of income, 14.5% ($n = 48$) were business owners, 12.7% (*n* = 42) were pastoralists, and 2.1% (*n* = 7) worked in the ecotourism sector. About 22.4% (*n* = 74 of 331) of the respondents selected 'other' as a source of income, which included casual workers or professions that I had not listed. Monthly median income in the study area was KES 15,000 (~USD 150). A majority of the respondents, 82.2% (*n* = 272 of 331), reported that their monthly income had declined or had not changed compared to the previous year, whereas 5.7% (*n* = 19) of the respondents did not provide a response. Only 12.1% (*n* = 40) reported an increase to their monthly income compared to the previous year.

More than a third of the respondents (35.9%, *n* = 119 of 331) identified that they used giraffe parts at least once in their lifetimes. Giraffe parts were most often used for consumption (71%; *n* = 184 of 259) involving meat (63.6%; *n* = 117 of 184), bone (20.1%; *n* = 37 of 184), bone marrow (15.2%; *n* = 28), and tail (1.1%; *n* = 2). Slightly more than a quarter of the uses described (26.6%; *n* = 69 of 259) were trophy poaching of giraffes for skin (37.7%; *n* = 26 of 69), tail hair (26.1%; *n* = 18 of 69), tail (18.8%; *n* = 13 of 69), meat (7.2%; *n* = 5 of 69), bone (5.8%; *n* = 4 of 69), skull (1.4%; *n* = 1 of 69), bone marrow (1.4%; *n* = 1 of 69). Additionally, I had one report (1.4%) of giraffe fat being used in cultural rituals. The use of giraffe parts in traditional medicines was reported among 2.3% (*n* = 6 of 259) of the respondents and involved the incorporation of meat, skin, and bone marrow into remedies for chest pains and fever. Bow and arrow (29.4% *n* = 101 of 343) and a combination of bright lights and machetes (29.4%; *n* = 101 of 343) were the most common tools that poachers use to kill giraffes, followed by wire snares (21%; *n* = 72 of 343) and spears (16.6%; *n* = 57 of 343). Guns (0.3%; *n* = 1 of 343) were only used once (Fig. 3.2b).

More than a third of giraffe body parts used by respondents were acquired through a one-time supplier (35.8%; *n* = 87 of 243), with giraffe meat being attained in 58.6% (*n* = 51 of 87) of these transactions (Fig. 3.2a). There were 28 respondents who identified that they poached giraffes for meat (50%; $n = 14$ of 28), bone marrow (21.4%; $n = 6$ of 28), bones (14.3%; $n = 4$ of 28) or skin (14.3%; $n = 4$ of 28). More than 80% ($n = 32$ of 39) of the respondents stated that they acquired giraffe meat from widely-known markets (Fig. 3.2a). Among respondents that once used giraffe parts but stopped, 42% ($n = 50$ of 120) identified government laws as the strongest deterrent, followed by 21% ($n = 25$ of 120) of respondents who listed the inability to sell giraffe parts as a limiting factor. About 15% ($n = 18$ of 120) listed the combination of both government laws and inability to sell parts as the reason why they stopped using giraffe parts. Only one person (0.8%) stated to have lost interest in poaching giraffes as the reason for stopping to engage in the behaviour, while no respondent selected affordability of tools or identifying an alternative source of income as a deterrent.

Binary regression model results showed that three variables significantly related to using giraffe parts. Specifically, males were more likely to use giraffe parts ($\beta = 0.502$; $n = 155$; $p = 0.052$) than females within the Tsavo Conservation Area. I also found that individuals who owned land within the Tsavo Conservation Area ($\beta = 0.879$; $n = 227$; $p = 0.003$) and individuals that listed tourism as their primary source of income ($\beta = 2.233$; $n = 7$; $p < 0.027$) were statistically more likely to use giraffe parts compared to pastoralists (Table 2). Results from the ordinal logistic regression model results also showed that males ($\beta = 0.458$; $n = 155$; $p = 0.072$), tourism workers ($\beta = 1.782$; $n = 7$; $p = 0.039$), and individuals that owned land ($\beta = 0.290$; $n = 227$; $p = 0.003$) within the Tsavo Conservation Area were more likely to use giraffe parts multiple times (Table 3.2).

3.4. Discussion

I found that giraffe parts were used for consumption, medicines, and as trophies by about a third of surveyed members in local communities that occurred between Tsavo East and Tsavo West National Parks, Kenya. My findings elucidate the socioeconomic factors that relate with the use of giraffe body parts. Giraffe parts were most often acquired for human consumption. Bushmeat represents an important source of animal protein for many rural communities although quantifying the volume consumed remains a challenge for conservation given the illegal nature of the activity (Eniang et al. 2008; Hoffman and Cawthorn 2012; Reuter et al. 2016). Additionally, giraffe meat is often packaged as livestock meat and then sold in urban areas (Ouso et al. 2020). Giraffe meat has a strong flavor compared to common livestock meat found in butcheries, and is considered a delicacy in some cultures (Cunnison 1958; Muller et al. 2018). Additionally, a fully grown giraffe can provide approximately 650 kg of meat, bones, and bone marrow (Mitchell et al. 2017; Silberbauer 2020), which were all used for consumption in the study area. Trophy poaching of giraffes provided a conduit for crafting items such as bags (from skin), fly whisks (from tail), and bracelets (from tail hair), that are either used in traditional costumes or sold locally for financial gain. One respondent also acknowledged that giraffe fat was an important component of traditional rituals. The use of giraffe parts for traditional remedies was reported by only 2.3% (n = 6 of 259) of the respondents, stating efficacy in treating chest pains and fever. The low use of giraffe parts for traditional medicine could be attributed to adoption of sedentary lifestyles in historically pastoralist areas (Fratkin 2001; Western et al. 2019). The increase of human settlements in the study area has resulted in development of healthcare facilities, and as such, many rural communities in Kenya rely on public hospitals and clinics rather than traditional cures (Kirigia et al. 2002). Thus, it may be that the low levels of use of giraffe body parts for medicative purposes may result from access to modern medicine.

I found that respondents from households with more adults were less likely to use giraffe parts (Table 3.2). I speculate that this result could be due to a higher number of household inhabitants providing secondary sources of income. Recently, there has been an increase in households that rely on crop farming in East Africa as a means to diversify income and diet (Rufino et al. 2013). In my study area, I found crop farming was the primary occupation for almost half of the respondents (48.3%, n = 160 of 331) while pastoralists accounted for 12.7% (n = 42 of 331). Crop farming on the edge of protected areas fuels human-wildlife conflict (McNutt et al. 2017; Horgan and Kudavidanage 2020; Long et al. 2020), and many farmers use fences to protect their crops as well as demarcate portions of their land. However, fences have are a major threat to wildlife in southern Kenya (Kenya Wildlife Service 2008; Osipova et al. 2018). During my surveys, I found a discarded giraffe carcass on the farm of a respondent (Fig. 3.3), who reported accessing the giraffe for meat after the animal inadvertently became trapped in the fence. Fences have also become more common in the Tsavo Conservation Area as a result of recent infrastructural developments that have impacted land owners and increased human-wildlife interactions (Githaiga and Bing 2019; Nyumba et al. 2021). Interestingly, six respondents reported accessing giraffe parts via opportunistic means including fences as well as train or vehicle collisions. Individuals that acquired giraffe parts opportunistically mainly sought bones, bone marrow, skull, tail hair, and tail to use as trophies (Fig. 3.2a). However, opportunistic acquisition of meat accounted for only 8% (n = 10) of 74 respondents that reported using giraffe parts. I also found that land ownership was positively correlated with the use of giraffe parts. I found that 46.8% (n = 45 of 96) of landowners that used giraffe body parts acquired them opportunistically, through chance events where animals died near their farms or infrastructural developments. While the impacts of infrastructural development in the Tsavo Conservation Area on giraffe and other wildlife has been documented over time (Wato et al. 2006; Nyumba et al. 2021), these need to be included in updated management and grazing plans as a means to foster coexistence, reduce human-wildlife conflict, and importantly, monitor trade routes for use of animal parts.

Among the respondents that reported using giraffe parts at least once in their lifetime, a large majority utilized meat, bone, bone marrow, and skin. Meat and bones especially, which are used in stews and soups, were acquired from a diverse set of sources (Fig. 3.2a). Approximately 16% of the respondents procured giraffe body parts from widely-known markets, often disguised as livestock meat (Ouso et al. 2020), highlighting the nature of commercial trade of giraffe parts in the Tsavo Conservation Area. One-time suppliers, while infrequent, were the most common channel for acquiring giraffe parts. This could be because availability of animal parts and derived products in widely-known markets is often driven by supply shortfalls (East et al. 2005; McNamara et al. 2016), which is an important factor in areas where these transactions are illegal. Only 11.5% of respondents reported hunting giraffes for their own use. I acknowledge that this result may be an underestimate given the likelihood that respondents could have been concerned about self-incrimination despite my efforts to promote trust and anonymity. The Tsavo Conservation Area is surrounded by communities that historically used protected areas for various activities including hunting (Kusimba et al. 2005). However, given that poachers are subject to fines that were further increased in the Wildlife Conservation and Management Act of 2013, government laws have proven to be a strong deterrent compared to any other factor with more than 40% of respondents that had previously poached giraffes reporting that they disengaged in this illegal activity. With a median annual income of ~ KES 15,000 (~USD 150) in the study area, many of the respondents would face harsh financial penalties if caught poaching. Approximately 21% of respondents stated that they were unable to sell giraffe parts and, as such, stopped poaching. This could be a result of the ambiguity of descriptions provided in the laws. If a poacher is caught with giraffe meat, the minimum sentence (i.e., six months jail term, KES 30,000 fine, or both) would apply only if the accused could prove that primary use for the meat was consumption. However, in my results, I found that giraffe meat is also incorporated in traditional medicines and used as a trophy, which would attract a more severe penalty. In such cases, the harshest penalty of life imprisonment or a monetary fine of 20 million KES (~ USD 200,000) would be applicable, considering that giraffes are listed as endangered species in the Wildlife Conservation and Management Act of 2013 (Kenya Wildlife Service 2016). Thus, the comparatively low financial penalties for consumptive use of animal parts could potentially provide a gap in the law for individuals that face the strongest penalties of the Wildlife Conservation Management Act of 2013, including endangered species.

Since 1977, giraffe numbers have declined by 67% throughout their range in Kenya (Ogutu et al. 2016) although it remains unclear the ways in which poaching has affected this trend. I found that only 10% of respondents stopped poaching due to long travel distances required to locate giraffes or because giraffes are no longer found in their area. One of the most common ways used by poachers to kill giraffes included the use of bright lights to blind animals (often motorbike lights as well as bright flashlights), then quickly cutting down the target animal with a machete and packaging the parts for transport on a motorbike (Taita Taveta Wildlife Forum, pers. comm.). Herein, motorbikes served the dual purpose of providing lights to blind the target animals, and the means of transporting giraffe parts expediently so as to avoid detection from law enforcement. Given the intense penalties that can result from poaching in Kenya, these illegal activities are typically conducted in areas where ranger patrols are less intensive (Kyale et al. 2011; Asaka 2018). Bow and arrows, wire snares, and spears were also commonly used to target giraffes (Fig. 3.2b), although these tools could potentially give animals more time to escape (Fig. 3.4) or take longer to kill the target animal and acquire the giraffe body parts. In some landscapes, wire snares are readily available and thus, used more often to trap wildlife (Knapp et al. 2010; Mudumba et al. 2020). Given that poaching of giraffes is conducted with the use of readily-available tools, it is possible that these incidents are more common and intense in areas close to human settlements. As such, it is important to dedicate more research efforts in quantifying population-level effects of poaching (Dunn et al. 2021).

Considering that the majority of respondents to my survey were crop farmers and that there is documented increase of human-wildlife conflict in the Tsavo Conservation Area due to changes in the landscape (Ihwagi et al. 2015; Muteti et al. 2018), wildlife management policies should be centered around coexistence strategies in partnership with local communities. It is likely that poaching will persist if mitigation efforts are not adapted to the local context given the increase of human settlements and changes in land tenure systems occurring in southern Kenya (Seno and Shaw 2002; Greiner 2017; Nyumba et al. 2021). While I documented different uses of giraffe body parts in southern Kenya, additional studies are required to quantify the degree to which poaching has affected giraffe populations in Kenya. Giraffe body parts were commonly used for consumption and procured through a variety of means, which presents a persistent challenge to conservation authorities in the implementation of mitigation efforts. Additionally, because of the broad availability of tools used to hunt giraffes (e.g., lights, motorbikes, machetes, and snare wire) and diverse motivations for using giraffe body parts (Dunn et al. 2021), more robust analyses are needed to elucidate on the socioeconomic factors that relate with specific uses of giraffe body parts to inform interventions. I found that meat was the most-commonly used giraffe body part. Meat also had the most varied sources of procurement. Still, future research should undertake a broad market study to determine the extent of giraffe meat availability and identify common trade routes. Communities have shown willingness to adopt coexistence measures when they receive benefits from wildlife and are involved in conservation (Kimiti et al. 2016; Western et al. 2019). Given that it is unlikely that illegal hunting of wildlife will be mitigated without participation of local communities, it is important to incorporate traditional knowledge in wildlife management strategies. Understanding the different cultures and practices in poaching hotspots can enhance community-based conservation efforts (Dickman 2010; Montgomery et al. 2020). Importantly, this can also increase trust and collaboration with law enforcement (Challender and MacMillan 2014; Biggs et al. 2017), to address one of the enduring challenges of the 21st century in the Global South. It is only through the involvement and participation of multiple stakeholders within these coupled human and natural systems that novel solutions can be identified for long-term solutions.

Acknowledgements

My heartfelt gratitude to Ahmed, S., Kibwanga, J., Wario, M., Mwangeje, J., Kazungu, C., Kalingu, A., Mwazaule, L., Mwasi, M., Mwakoro, E., and Juma, A. for their assistance in collecting data and improving the clarity of the semi-structured survey in local languages. My thanks to the Leiden Conservation Foundation, Giraffe Conservation Foundation, Wildlife Conservation Network, African Wildlife Foundation, and National Geographic Society for their generous support that made this research possible.

APPENDIX

APPENDIX

Table 3.1. Descriptions and summaries of explanatory variables used in models assessing socioeconomic drivers that influence the use of giraffe (*Giraffa tippelskirchi*) body parts in the Tsavo Conservation Area, southern Kenya. These data were collected between June and July 2019 via face-to-face interviews with households (*n* = 331) inhabiting the conservation area.

Variable	Description	Value type and summary
No. of use	Number of times household has used giraffe parts	*Categorical* 1-10: *n* = 109 (32.9%) 11-20: *n* = 5 (1.5%) 21-30: *n* = 0 more than 30 times *n* =5 (1.5%) never: *n* = 212 (64.1%)
Gender	Gender of respondent	*Binary* M: *n* =155 (46.8%) F: *n* = 176 (53.2%)
Occupation	Primary source of income of the household	*Categorical* Pastoralist: *n* = 42 (12.7%) Crop farmer: *n* =160 (48.3%) Tourism worker: *n* = 7 (2.1%) Business owner: *n* = 48 (14.5%) Other: *n* = 74 (22.4%)
Income_change	Assesses whether the monthly income of the household has changed in the past year	*Likert scale* (3) decreased: *n* = 167 (50.45%) has not changed: *n* = 105 (31.7%) increased: *n* = 40 (12.1%) I don't know: *n* = 19 (5.7%)
Origin	Assesses whether respondents were born in current residence area or different community	*Binary* Here: *n* = 240 (72.5%) Different area: (*n* = 91, 27.5%)
Education	Highest level of education of respondent	*Categorical* Primary: *n* = 191 (57.7%) Secondary: *n* = 51 (15.4%) College: *n* = 24 (7.2%) University: *n* = 4 (1.2%) None: *n* = 42 (12.7%) No response: *n* = 19 (5.74%)

Table 3.1. (cont'd)

Variable	Description	Value type and summary
Land	Whether household owns land or not	*Binary* Yes: n = 227 (68.6%) No: n = 104 (31.4%)
Land_type	Type of land ownership system in household	*Categorical* *(N = 227) Family: n = 196 (86.3%) Community land: n = 25 (11.1%) No response: n = 6 (2.6%)
Over_18	Number of adults (aged 18 and above) residing in household	*Numerical* Mean = 3.4 SD = 2.2 Range = 1-14
Under_18	Number of individuals aged younger than 18 residing in household	*Numerical* Mean = 3.7 SD = 2.9 Range = 0-23

Table 3.2. Model parameter estimates, standard errors and statistical significance from the ordinal and binary logistic models predicting correlations to use of giraffe (*Giraffa tippelskirchi*) parts. I fit the model using data from 331 household surveys in the Tsavo Conservation Area, southern Kenya in 2019. Variable descriptions are provided in Table 3.1. *p*-values: ***<0.01; **<0.05; *<0.1.

	Binary logistic regression				**Ordinal logistic regression**			
Parameter	**Estimate**	**SE**	**z-value**	**P(>|z|)**	**Estimate**	**SE**	**z-value**	**P(>|z|)**
Intercept	-1.737	0.662	-2.622	0.009***				
$Gender_{Male}$	0.502	0.258	1.941	0.052*	0.458	0.254	1.800	0.072*
$Occupation_b$	0.020	0.389	0.051	0.959	-0.039	0.392	-0.100	0.921
$Occupation_c$	2.233	1.007	2.218	0.027**	1.782	0.862	2.067	0.039**
$Occupation_d$	0.386	0.493	0.784	0.433	0.281	0.489	0.575	0.565
$Occupation_e$	-0.128	0.457	-0.280	0.780	-0.185	0.460	-0.403	0.687
$Income\_Change_b$	0.223	0.284	0.784	0.433	0.163	0.282	0.576	0.565
$Income\_Change_c$	-0.452	0.451	-1.004	0.316	-0.499	0.446	-1.121	0.262
$Income\_Change_d$	0.453	0.551	0.822	0.411	0.302	0.533	0.566	0.571
$Origin_b$	0.284	0.285	0.994	0.320	0.251	0.280	0.895	0.371
$Land_{Yes}$	0.879	0.294	2.985	0.003***	0.863	0.290	2.971	0.003***
$Education_b$	-0.253	0.371	-0.680	0.496	-0.209	0.365	-0.571	0.568
$Education_c$	0.352	0.485	0.726	0.468	0.312	0.472	0.661	0.509
$Education_d$	0.583	1.161	0.502	0.616	0.435	1.067	0.408	0.683
$Education_e$	0.322	0.523	0.615	0.539	0.251	0.509	0.493	0.622
$Education_f$	0.404	0.404	1.000	0.317	0.519	0.405	1.282	0.200
over_18	-0.067	0.066	-1.015	0.310	-0.081	0.066	-1.225	0.221
under_18	0.050	0.047	1.083	0.279	0.072	0.046	1.550	0.121

Figure 3.1.

Map showing the study area where household surveys were conducted in the Kasigau Corridor of the Tsavo Conservation Area in June and July 2019 to assess the use of giraffe (*Giraffa tippelskirchi*) parts.

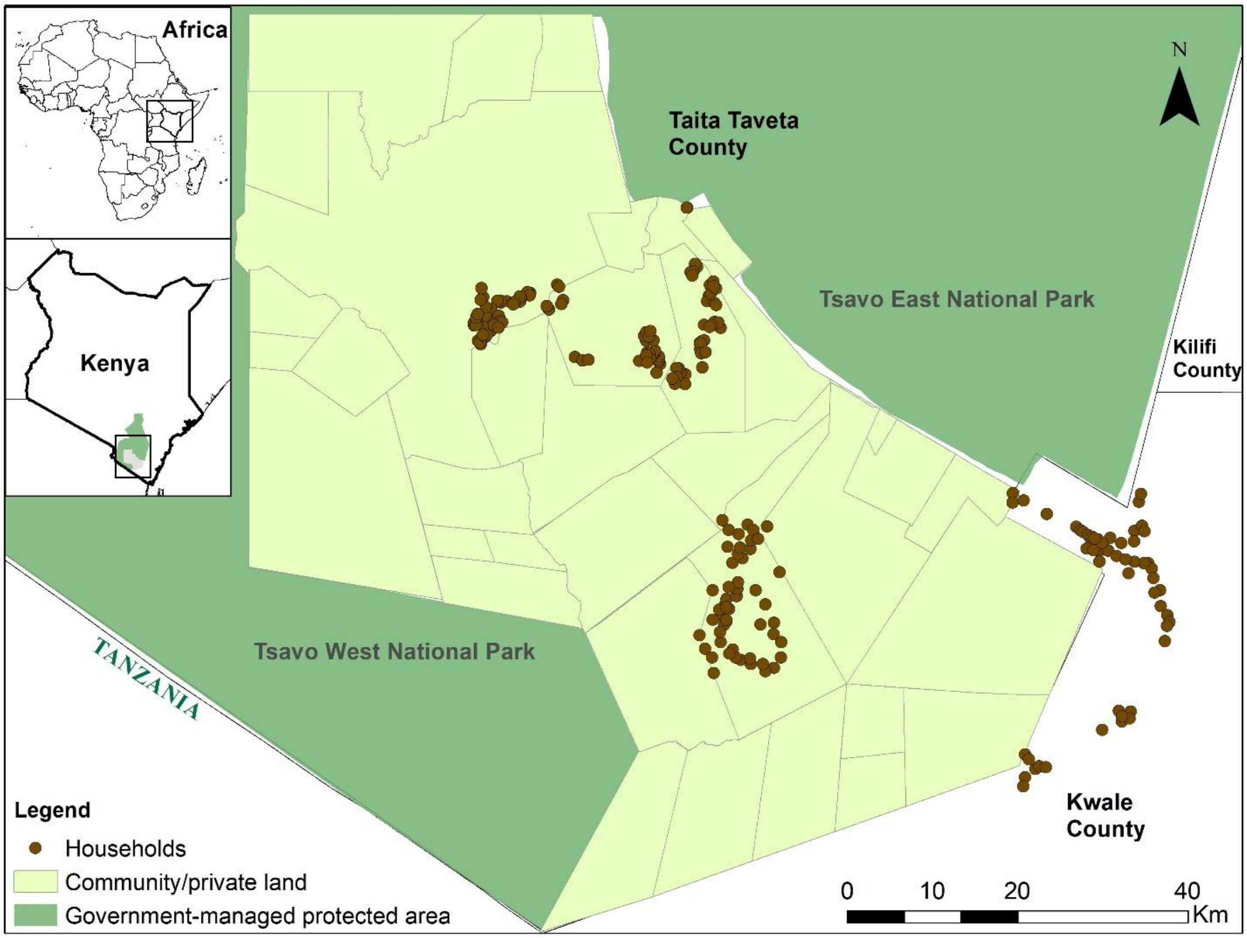

Figure 3.2.

Sources of reported giraffe (*Giraffa tippelskirchi*) parts used in households within the Tsavo Conservation Area, southern Kenya (panel a). Figures were obtained from members in 119 households that reported using giraffe parts at least once during the survey. Panel b depicts the documented types of tools used to poach giraffes within the Tsavo Conservation Area and their frequency of use.

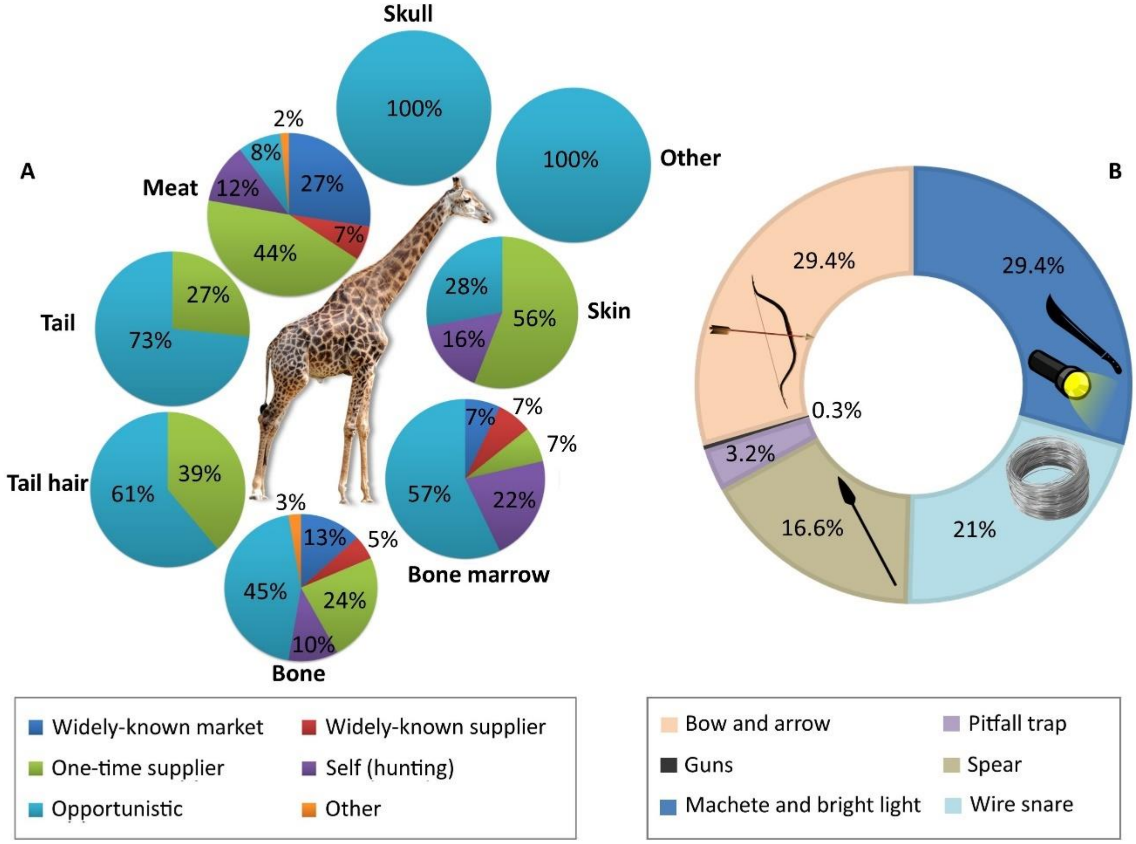

Figure 3.3.

Giraffe (*Giraffa tippelskirchi*) calf trapped in a fence in southern Kenya (panel a). The calf was successfully removed from the fence following intervention from veterinary doctors of the Kenya Wildlife Service. In some instances, the veterinary team may not arrive on time and the giraffe dies, in which case individuals opportunistically acquire meat and other parts for use, as panels b and c depict the remains of a giraffe that was consumed in the Tsavo Conservation Area.

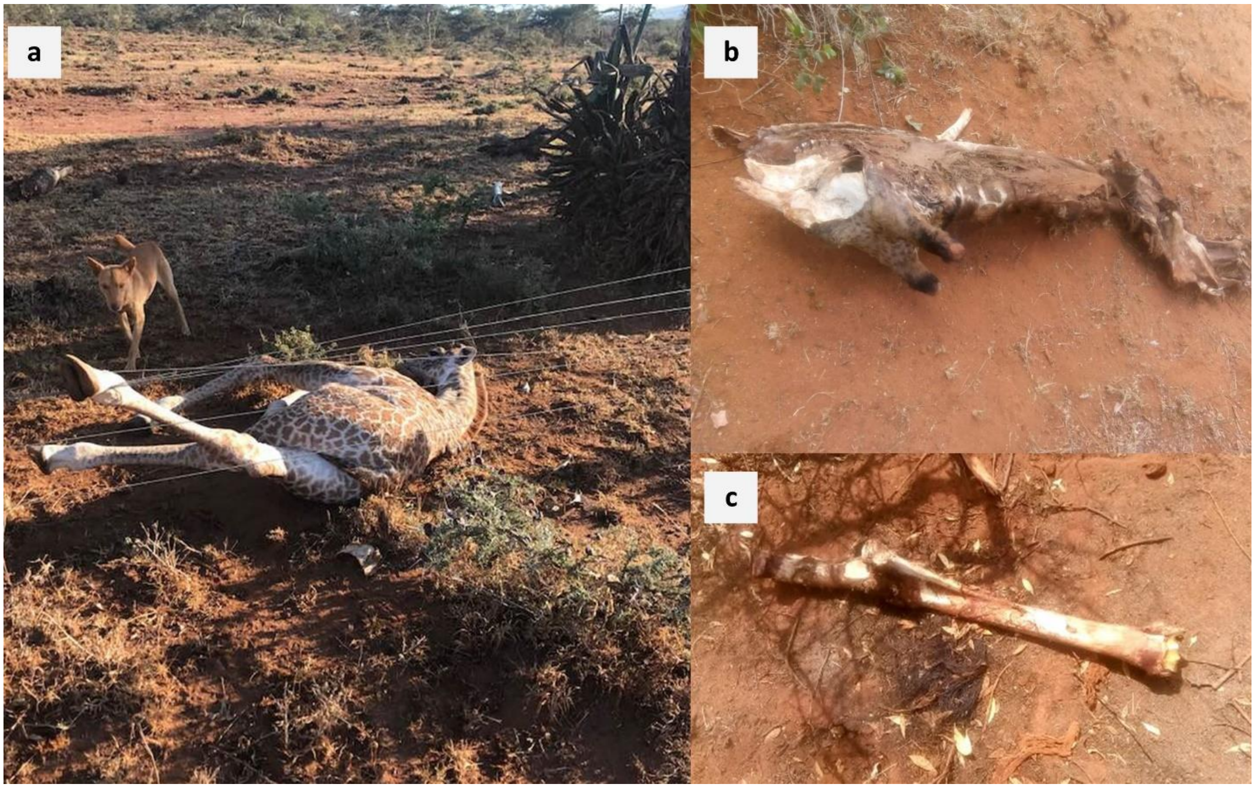

Figure 3.4.

Giraffe (*Giraffa tippelskirchi*) being treated for an arrow wound by Kenya Wildlife Service veterinary doctors after escaping an illegal hunting attempt in southern Kenya.

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CHAPTER 4: THE COMPLEX WAYS IN WHICH LANDSCAPE CONDITIONS AND RISKS AFFECT HUMAN ATTITUDES TOWARDS WILDLIFE

Abstract

People and wildlife interact in a variety of ways within coupled human and natural systems. These interactions can be benign or yield positive or negative outcomes for humans and/or wildlife. Interactions that potentially yield negative outcomes for humans (i.e., those that present risks to human security or private or property) can lead to retaliation, triggering what is broadly referred to as human-wildlife conflict. The nature and strength of these human responses may not only depend on previous interactions with wildlife but might also be shaped by landscape conditions such as drought, or forage availability. However, the ways in which previous experiences and landscape conditions interact to shape peoples' attitudes of wildlife is not well-understood. I set this study in the Tsavo Conservation Area in southern Kenya, which experiences some of the highest rates of human-wildlife conflict documented in East Africa, and explored how previous experiences with wildlife and landscape conditions interact to inform attitudes of local people towards wildlife. I conducted semi-structured surveys among 331 households located in the Tsavo Conservation Area and fit an ordinal mixed-effects regression model to predict human attitudes towards wildlife as a function of landscape conditions and previous interactions with wildlife. Respondents indicated that baboons, elephants and lions posed the greatest risks to both human security and private property. Households that experienced previous risks from wildlife in their villages desired those wildlife populations to decrease ($\beta = -0.93$; $n = 261$; $p < 0.05$), whereas households requiring grazing lands but cannot access them in the study area desired to see those wildlife populations increase ($\beta = 0.86$; $n = 251$; $p < 0.01$). This study demonstrates that human-wildlife interactions have important spatial context. Specifically, these interactions are not uniform across households in the same area due

to the location of private property. Correspondingly, for conservation interventions to be most effective, I recommend that they consider local contexts and landscape conditions of communities.

4.1. Introduction

Wildlife are integral components of ecosystem structure, and central to the cultural heritage of people in coupled human and natural systems around the world (Mainka et al. 1995, Bobo and Ntumwel 2010, Bhatia et al. 2017). In many cultures, for example, wildlife are depicted as spiritual totems, designated as national symbols, or are central figures in storytelling (Mukul et al. 2012, Bortolamiol et al. 2018, Fernández-Llamazares and Cabeza 2018). The role of animals in human culture has led to development of independent policies for wildlife management maintained by certain indigenous tribes (Ikanda and Packer 2008, Negi 2010, Jimoh et al. 2012). Thus, normative behaviours and attitudes of people towards wildlife are important components of local, municipal, domestic, and international conservation and management philosophies (Manfredo and Dayer 2004, Teel et al. 2007). In the cognitive hierarchy model of human behaviour (Fulton et al. 1996), attitudes are influenced by basic belief patterns, which are often slow-changing, and are typically classified as being either positive or negative (Vaske and Donnelly 1999). Human attitudes are also informed by memory and considered a directional evaluation of specific events in time (Lischka et al. 2018). Correspondingly, human behaviour, which is informed by those attitudes, is contextual and temporally dynamic (Fulton et al. 1996). As such, a key component of the creation and implementation of viable conservation strategies is to quantify human attitudes of wildlife (Treves et al. 2009, Baruch-Mordo et al. 2011, Espinosa and Jacobson 2012).

The outcomes of human-wildlife interactions can be benign, positive, or negative (Morzillo et al. 2014). For instance, photographic tourism in protected areas can be a positive interaction for humans in that observing animals can induce a deep sense of wellbeing and fulfilment (Setchell et al. 2017, Dou and Day 2020). This fulfilment is intrinsically linked to recognition that wildlife are essential parts of a healthy ecosystem (Curtin 2009). However, people who share landscapes with wildlife can experience negative interactions which can trigger human-wildlife conflict (Peterson et al. 2010, König et al. 2020). Negative interactions often derive from risks that wildlife pose to human security or private property (Kretser et al. 2009). The severity and/or frequency of these risks inform human conceptualizations of certain wildlife species as problematic (McIvor and Conover 1994, Hoare 2012). Given the frequency of negative human-wildlife interactions globally, conflict presents an important challenge for human well-being and wildlife conservation (Treves et al. 2006, Redpath et al. 2015, Anand and Radhakrishna 2017).

Negative human-wildlife interactions and subsequent conflict that may emanate, can be particularly severe in the Global South where humans living adjacent to protected areas often reside in systems with comparatively high faunal biodiversity (Distefano 2005, Seoraj-Pillai and Pillay 2017, Ontiri et al. 2019). East Africa, for example, has experienced an increase in human-wildlife conflict coinciding with expansion of human settlements in the periphery of protected areas (Myers et al. 2000, Kaswamila 2009, Ogutu et al. 2014). In this region, smallholder farming accounts for about 75% of agricultural production, and farmers also tend to keep livestock (Njarui et al. 2016). As such, agro-pastoral systems featuring both farming and livestock husbandry provide a primary source of income for a large portion of the rural population (Salami et al. 2010). Wildlife that roam into these agro-pastoral human settlements raid crops, depredate livestock, and threaten the security of local people (Tweheyo et al. 2005, Abade et al. 2014, Chaka et al. 2020). These risks include physical injury, damage to infrastructure, and weakened food security, all of which can disrupt psychosocial wellbeing (Ogra 2008, Barua et al. 2013, Goodale et al. 2015). Correspondingly, people may seek to remove 'problem' animals or convert habitats to minimize risks to human security or private property (Treves et al. 2009, Dunham et al. 2010, Acharya et al. 2016). Additionally, non-problematic wildlife may also be subject to human retaliation, which can scale to deleterious population-level consequences (Treves et al. 2006, Virani et al. 2011, Swanepoel et al. 2014, Jędrzejewski et al. 2017).

Within the East African region, Kenya has experienced high levels of human-wildlife conflict. An estimated 60% of the country's wildlife inhabit land that is outside government-managed protected areas (Western et al. 2009). Human-wildlife conflict is especially intense in northern (Laikipia, Meru, and Samburu counties) and southern (Kajiado, Narok, and Taita-Taveta counties) Kenya, where areas used by wildlife have a high degree of overlap with human community lands (Ogutu et al. 2016, Long et al. 2020). In these systems, productivity of the land for keeping livestock and growing crops presents a primary source of income (Gross et al. 2019, Mukeka et al. 2019, Long et al. 2020). Consequently, landscape conditions are particularly important in understanding mechanisms associated with human-wildlife conflict. For example, water availability and access to grazing lands for livestock are necessary elements for wildlife population persistence and human well-being. Thus, competition over these increasingly scarce resources may exacerbate human-wildlife conflict (Sangay and Vernes 2008, Karanth and Kudalkar 2017). In these instances, communities experience conflict with wildlife because water quality deteriorates after use by wildlife, or forage is consumed by wildlife at a faster rate compared to livestock, thus affecting human livelihoods (Ocholla et al. 2013). However, it remains unclear how previous interactions with wildlife and underlying landscape conditions would inform human attitudes of wildlife. Here, I sought to document whether local people subjected to wildlife risks would prefer to see those wildlife populations decrease, remain at the present levels, or increase and under what landscape conditions.

I assessed human attitudes of wildlife posing the greatest risks to human security (e.g., aggression towards people) or private property (e.g., crop raiding, livestock depredation, or damage to human structures) in the Tsavo Conservation Area (hereafter referred to as Tsavo), in southern Kenya. I positioned this study in Tsavo, because it experiences the highest levels of human-wildlife conflict documented in Kenya (Long et al. 2020, Mukeka et al. 2020). I selected species of wildlife that were most associated with human-wildlife conflict or commonly interacted with humans in the village lands of Tsavo. I then administered semi-structured surveys to individuals living in the villages to assess whether human attitudes (as inferred from desired population-level changes) of these species varied according to risks to human security or private property and landscape conditions of the area (i.e., drought, access to grazing land, access to water, land degradation, conflicts with local leaders or government officials). Human and wildlife behaviours are predominantly studied as drivers of conflict (Gross et al. 2019, Kissui et al. 2019, Mukeka et al. 2019), but there is a need to incorporate other domains of human-wildlife conflict to identify long-lasting solutions (Montgomery et al. 2018). Therefore, I place the results of this study within local contexts where sustainability of human-wildlife conflict mitigation efforts must align with the diverse heritage of local communities (*sensu* Montgomery et al. 2020).

4.2. Methods

4.2.1. Study area

Covering approximately 60,000 km^2, the Tsavo landscape is one of Kenya's most important coupled human and natural systems. Annual rainfall in Tsavo varies from ~300 mm to 1,200 mm, giving rise to a number of seasonal rivers (Oremo et al. 2019) that support different habitats and a taxonomic diversity of wildlife. The landscape is characterized by a mix of open savannahs and woodlands with comparatively large populations of carnivores and ungulates (Henschel et al. 2020). Within this matrix of protected areas, including two of Kenya's largest national parks, are human villages (Fig. 4.1). Tsavo covers approximately two-thirds of Taita-Taveta County, and almost a third of the human population is found in Voi town center, which has ~110,000 inhabitants and ~32,000 households (Kenya National Bureau of Statistics 2019). While the killing of wildlife is illegal in Kenya under the Wildlife Conservation and Management Act of 2013, an offender may not be prosecuted in cases of human-wildlife conflict, provided that; 1) there is sufficient evidence that the risks that the target animal poses warrants lethal retaliation and 2) the killing occurred outside protected areas (Kenya Wildlife Service 2016). Any killing of wildlife, whether they pose risks to human security /private property or not, inside protected areas is punishable by law (Kenya Wildlife Service 2016).

I initially verified wildlife species that threaten human security and private property in six administrative areas of Kasigau, Mackinon, Marungu, Mwachabo, Mwatate, and Sagalla. I selected these areas because of their involvement in the Kasigau Corridor REDD+ (Reducing Emissions from Deforestation and forest Degradation in developing countries) project. I held two consultative meetings with research assistants affiliated with the Wildlife Works Kasigau

Corridor REDD+ project to determine species that frequently posed risks to human security or private property (i.e., crops, livestock, or human structures) in Tsavo. Via this process, I selected 11 common species including large carnivores (cheetahs (*Acinonyx jubatus*), leopards (*Panthera pardus*), lions (*P. leo*), and spotted hyenas (*Crocuta crocuta*)), large herbivores (African savanna elephants (*Loxodonta africana*), buffalo (*Syncerus caffer*), giraffe (*Giraffa tippelskirchi*), hippopotamus (*Hippopotamus amphibius*), and zebra (*Equus quagga*)), as well as yellow baboons (*Papio cynocephalus*) and mongooses (*Herpestes ichneumon*).

4.2.2. Household surveys

Between June and July 2019, I administered semi-structured surveys to residents in six administrative locations within the study area (Fig. 4.1). Semi-structured surveys are used in instances where there is a lack of subjective knowledge of phenomena and participants are free to respond to open-ended questions included the survey (McIntosh and Morse 2015). Researchers may also probe responses to ensure that participants reflect on their experiences, following a certain order or 'structure' of questions (Leech 2002, Whiting 2008). In this study, I used this technique to determine whether people's attitudes of wildlife varied according to landscape conditions and types of risks posed by wildlife. I trained 10 research assistants from local communities, who were conversant with the REDD+ project and familiar with the study area to: *i*) improve clarity of the questionnaire, *ii*) translate responses from local languages and *iii*) assist in conducting the surveys. I selected households via simple random sampling at the start of each day, where I interviewed participants in the first house closest to the road. Subsequent households within a day were again selected at random with a minimum distance of two kilometres between residences. To initiate each survey, I explained the context and objective of my research and offered a consent form to respondents. Consent was given verbally by the respondents and recorded in writing by the surveyors. I explicitly explained that the survey could be terminated at any time of the respondent's choosing. All research protocols and survey instruments were approved by the Michigan State University Institutional Review Board (study id 00001610) and the National Commission for Science and Technology of Kenya (permit number NACOSTI/P/20/5611).

The first part of my survey evaluated the frequency with which respondents encountered the 11 focal species of wildlife. I then asked respondents to evaluate whether they had experienced risks to human security (i.e., threatened, chased aggressively by wildlife, injured by wildlife, or knew of a person killed by wildlife) or private property (i.e., crop raiding, livestock depredation, or any other risk that I had not listed) from these species. I also documented social factors such as primary means of income, whether a member of the household owned land in Tsavo, and type of ownership system (family inheritance or community land). Next, I asked respondents about landscape conditions that could have impacted their villages such as drought, land degradation, conflicts with local leaders, clashes with government officials, clashes with neighbouring communities, access to grazing land, access to water or any other condition that I had not listed. Finally, I assessed people's attitudes of the 11 wildlife species based on respondent's interests to see their populations decrease (-1), remain the same (0), or increase (1) within the next five years.

4.2.3. Data analysis

I fit an ordinal mixed-effects regression model predicting respondent attitudes of wildlife (i.e., negative (-1), neutral (0), or positive (1)) as a cumulative link function of wildlife risks and landscape conditions (see Table 4.1 for predictor variables). I included village ID as a random effect using adaptive Gauss-Hermite quadrature approximation to account for any spatial dependences in my survey design (Pan and Thompson 2003). Among the model diagnostic procedures, I assessed collinearity among predictor variables and sequentially eliminated correlated variables based on variance inflation factors >3.0 (Harrell 2016). After removal of collinear covariates, I fit a global five parameter model and examined significance at an alpha level of $p < 0.05$. I opted for the global model given that my interest was in prediction, and regression models provide a means towards interpolative predictive accuracy considering that the additional parameters reduce variation around the estimated regression function and decrease chances of omitted variable bias (Moll et al. 2016). I completed all analyses in R v4.0.3 (R Core Team 2020) using the packages *brant*, *MASS*, *ordinal*, and *rms* (Brant 1990, Harrell 2016, Bürkner and Vuorre 2019).

4.3. Results

Between June and July 2019, I completed 331 semi-structured surveys among 350 households given that 19 households stopped the interviews midway. The average size of a household was 7.1 (range 1 – 37) people. About half of the respondents (48.3%; n = 160 of 331) were crop farmers, 14.5% (n = 48) listed small business as their primary source of income, 12.7% (n = 42) were pastoralists, 2.1% (n = 7) were employed in the ecotourism sector, and 22.4% (n = 74) listed other sources of income (such as teacher, miner, and motorbike rider). More than two-thirds of the households owned land (68.6%, n = 227) and among those individuals, 86.3% (n = 196 of 227) inherited that land from family members while 11.1% (n = 25 of 227) owned land through community conservancies or ranches. Approximately 2.6% (n = 6 of 227) of the landowners elected not to describe the structure of their land ownership system.

Almost 90% (n = 292 of 331) of households previously experienced crop raiding, 57.1% (n = 189) suffered from livestock depredation, and 11.8% (n = 39) knew a member of their community that had been injured or killed by wildlife. Furthermore, 70% of respondents (n = 218 of 314) experienced being chased aggressively by wildlife. About 4.5% (n = 14 of 314) of respondents directly experienced elephant damage to their homes or other human infrastructure (Table 4.1). Respondents stated that baboons (76.1%; n = 239 of 331), elephants (69.1%; n = 217), zebra (22.6%; n = 71) and buffaloes (14.6%; n = 46) were the species predominantly associated with crop raiding. Respondents also indicated that baboons (30.9%; n = 97 of 314), lions (30.3%; n = 95), hyena (11.8%; n = 37), mongoose (7.6%; n = 24) and leopard (3.5%; n = 11) either injured or killed their domestic animals. Respondents had previous experience of elephants (60.2%; n = 189 of 314), baboons (28.7%; n = 90), lions (10.5%; n = 33) and hippopotamus (2.9%; n = 9) threatening human security. Considering these interactions, baboons, elephants, and lions were the three species described to pose greatest risks to both human security and private property (Fig. 4.2). No species was reported to pose risks only to human security.

Results from the ordinal mixed-effects regression model showed that two covariates significantly predicted human attitudes of wildlife (Table 4.2). Respondents that experienced previous risks from wildlife in their villages wanted wildlife numbers to decrease (Table 4.2) and thus were more likely to have negative attitudes of wildlife ($\beta = -0.93$; n = 261; $p < 0.05$). , and thus would want wildlife numbers to decrease (Table 4.2). Respondents who had limited or no access to grazing lands for livestock they owned had positive attitudes toward wildlife ($\beta = 0.86$; n = 251; $p < 0.01$).

4.4. Discussion

The results of my analysis demonstrate that past, risky experiences with wildlife and whether respondents owned grazing lands for livestock significantly affected human attitudes toward wildlife. Human-wildlife conflict is one of the most important challenges facing wildlife conservation and human well-being in southern Kenya (Ogutu et al. 2014, Mukeka et al. 2020) and beyond (Riddle et al. 2010, Jędrzejewski et al. 2017, Margulies and Karanth 2018). A large portion of respondents were crop farmers living in an area heavily used by wildlife (Ngene et al. 2017, Henschel et al. 2020). These conditions (i.e., agro-pastoral system with high population numbers of wildlife and humans) led to a high number of interactions between humans and wildlife. Human settlements in the study area occur in a wildlife corridor between the government managed Tsavo East and West National Parks (Fig. 4.1). Additionally, recent infrastructure development, including construction of a standard gauge railway and proliferation of fences in Tsavo, has altered movement patterns of wildlife (Mukeka et al. 2018, Nyumba et al. 2021). Elephants in Tsavo for instance, exhibit behavioural responses that commonly occur in stressful conditions or risky landscapes near these infrastructural developments, which are adjacent to human settlements (Okita-Ouma et al. 2021). While use of fences in some areas may temporarily protect private property and enhance human security, fences can alter wildlife movements resulting in similar problems for unfenced neighbors (Osipova et al. 2018). More than half of respondents knew of aggressive behaviour by wildlife, had experienced crop damage, and livestock depredation (Fig. 4.3), suggesting that negative interactions with wildlife are common in Tsavo. This is because almost half of the respondents were smallholder farmers, who depended on land and livestock as a primary means of income.

Most respondents felt that species that posed risks to human security and private property had increased in population numbers over the past five years. Recent surveys in Tsavo support these perceptions as elephant and buffalo populations are currently at their highest levels since the 1980s (Ngene et al. 2017). Across this same time period, livestock numbers in Tsavo have also expanded due to the increase of smallholder farmers and pastoralists who keep large herds to provide for their households (Ogutu et al. 2016). I posit that growth of both wildlife and livestock populations increased competition for resources which exacerbates human-wildlife conflict. For instance, while drought and disease can lead to crop loss, crop damage from wildlife is often perceived with more bitterness among local people (Tweheyo et al. 2005). Interpretation of the model output showed that people who had previously experienced risks from wildlife in their villages desired to see wildlife populations decrease in the next five years. This trend, however, was influenced by where the households were located. For instance, risks of crop raiding and livestock depredation are typically high in and among human settlements adjacent to conservation areas (Fig. 4.3). These risks can also increase in intensity in landscapes where people feel threatened by high numbers of wildlife that may not typically pose risks when in low numbers (Messmer 2000, Nyhus 2016). Given that human response to risks posed by wildlife can be disproportionate in such instances (Messmer 2000, Hudenko 2012, Margulies and Karanth 2018), it is important to develop management plans that address resource use of both wildlife and humans. For instance, grazing plans that are linked to wildlife management plans and landscape conditions of specific areas can enhance coexistence (Cros et al. 2004, Vavra 2005). As such, wildlife management and grazing strategies should be incorporated into spatial plans of local governments to nurture both conservation and development practices.

Landscape conditions also influenced human attitudes towards wildlife. I found that people with limited or no access to grazing lands for their livestock tended to have positive attitudes of wildlife (Table 4.2). While there are private and community ranches in Tsavo (Fig. 4.1), both Tsavo East and West National Parks provide important sources of pasture for livestock during the dry season (Ngene et al. 2017). Thus, I hypothesize that households that had positive attitude towards wildlife despite having no access to grazing lands, recognized the indirect benefit of alternative sources of pasture in protected areas during the dry season (Waweru and Oleleboo 2013, Masiaine et al. 2020). It is important to note that most of the local communities in Tsavo used to graze their livestock in lands that were eventually gazetted as Tsavo East and West National Parks in 1948, well before Kenya's independence (Seno and Shaw 2002). However, in present times, the practice of grazing livestock in national parks is illegal and perpetrators are subject to considerable financial penalties (Kenya Wildlife Service 2016). Additionally, wildlife management authorities have expressed difficulties in arresting livestock owners that illegally grazed livestock in national parks (Malemba 2016). In most cases, children accompany livestock and as such, law enforcement personnel are forced to review infringements on a case basis (Gikunda 2016, Malemba 2016). As an alternative to grazing livestock in national parks, some of the private and community wildlife ranches in Tsavo charge pastoralists a fee to graze livestock (Heath 2001). This option may not be tenable for individuals with large herds of livestock, considering that fees can be prohibitive (ranging from KES 200 (~USD 2) to KES 500 (~USD 5) per head of livestock; Heath 2001). Recognizing the history and vulnerability of people who share landscapes with wildlife that potentially pose risks to their livelihoods, especially during dry seasons, can have positive impacts and provide indirect benefits (Lesorogol 2008, Hazzah et al. 2017). For instance, seasonal agreements between land owners and pastoralists can promote positive attitudes toward wildlife and coexistence (Goldman 2003, Mbane et al. 2019).

Human-wildlife conflict is a global and complex problem that will require creative solutions (Hoare 2012, Beck et al. 2019, Montgomery et al. 2020). Future studies examining the severity and cost of various wildlife risks can provide crucial information on these aspects by conducting more robust analysis. While the importance of exploring the interdisciplinary domains that are inherent to conflict has been highlighted (Montgomery et al. 2018), I advocate for consideration of the ways in which landscape conditions and the spatial context of risk may influence human perceptions of conflict. Landscape conditions for example have received little attention in human-wildlife conflict studies even though they may also directly or indirectly influence risks that wildlife pose to human security and private property (Abade et al. 2014). Wildlife managers need to incorporate traditional knowledge and practices adapted to the local context to mitigate human-wildlife conflict (Dickman 2010, Karanth and Kudalkar 2017). As such, mitigating risks that wildlife pose to human security and private property requires approaches that address both social and environmental factors that vary both temporally and spatially (Mukeka et al. 2018). This study demonstrated that despite inherent risks to human security and private property posed by wildlife, people’s attitudes of wildlife should be interpreted in consideration of landscape conditions of the study area.

Acknowledgements

This research was realised through grants from the Giraffe Conservation Foundation, Leiden Conservation Foundation, Wildlife Conservation Network, African Wildlife Foundation, and National Geographic Society. I thank Ahmed, S., Kibwanga, J., Wario, M., Mwangeje, J., Kazungu, C., Kalingu, A., Mwazaule, L., Mwasi, M., Mwakoro, E., and Juma, A. for their assistance in collecting data and improving the clarity of the semi-structured survey in local languages.

APPENDIX

APPENDIX

Table 4.1. Descriptions and summaries of explanatory variables used in models assessing attitudes towards wildlife by respondents who have experienced risks to human security and private property posed by wildlife. The data were collected between June and July 2019 via semi-structured surveys with residents inhabiting Tsavo, southern Kenya.

Variable	Description	Value type and summary
Wildlife change	Assesses whether respondent would want wildlife numbers to change in next five years	*Likert scale* (3) Decrease: n = 54 (17.2%) Remain the same: n = 235 (74.8%) Increase: n = 25 (8%)
Threatened	Assesses whether member of household has been aggressively chased by wildlife	*Binary* No: n = 96 (30.6%) Yes: n = 218 (69.4%)
Crop raiding		*Binary* No: n = 22 (7%) Yes: n = 292 (93%)
Livestock injured/killed		*Binary* No: n = 125 (39.8%) Yes: n = 189 (60.2%)
Person injured/killed		*Binary* No: n = 275 (87.6%) Yes: n = 39 (12.4%)
Other (house destroyed)		*Binary* No: n = 300 (95.5%) Yes: n = 14 (4.5%)
Drought	Whether respondents have been directly affected by drought in the study area	*Binary* No: n = 2 (0.6%) Yes: n = 312 (99.4%)
Animal or crop disease	Whether respondents have been directly impacted by animal or crop disease	*Binary* No: n = 8 (2.6%) Yes: n = 299 (97.4%)
Access to grazing lands	Whether respondents are affected by access to grazing lands	*Binary* No: n = 54 (17.7%) Yes: n = 251 (82.3%)
Access to water	Whether respondents are affected by problems relating to access to water	*Binary* No: n = 42 (13.4%) Yes: n = 272 (86.6%)
Wildlife risk	Whether respondents previously experienced risks posed by wildlife in landscape	*Binary* No: n = 45 (14.7%) Yes: n = 261 (85.3%)

Table 4.1. (cont'd)

Variable	Description	Value type and summary
Conflict with local leaders	Whether respondents are impacted by conflicts with local leaders	*Binary* No: n = 125 (44%) Yes: n = 159 (56%)
Conflict with government officials	Whether respondents are affected by conflicts with government officials	*Binary* No: n = 123 (43.9%) Yes: n = 157 (56.1%)
Conflict with neighbouring communities	Whether respondents are affected by conflicts with neighbouring communities	*Binary* No: n = 140 (47.6%) Yes: n = 154 (52.4%)

Table 4.2. Model parameter estimates, standard errors, and statistical significance from the ordinal logistic regression model predicting attitudes toward wildlife as a function of risks posed by wildlife and landscape conditions that impact households directly in Tsavo, southern Kenya. I fit the model using data from 331 household surveys. Variable descriptions are provided in Table 1. *p*-values: ***<0.01; **<0.05; *<0.1

Parameter	**Estimate**	**SE**	***z*-value**	***p*-value**
$\text{Threatened}_{\text{Yes}}$	-0.18	0.30	-0.58	0.56
$\text{Person\_injured\_or\_killed}_{\text{Yes}}$	0.22	0.43	0.52	0.60
$\text{House\_damage}_{\text{Yes}}$	0.49	0.63	0.77	0.44
$\text{Conflict\_wildlife}_{\text{Yes}}$	-0.93	0.41	-2.27	0.02**
$\text{Access\_grazing\_land}_{\text{Yes}}$	0.86	0.34	2.48	0.01***

Figure 4.1.

Location where household surveys were conducted between June and July 2019 to assess the different human-wildlife interactions in Tsavo, southern Kenya. The Kasigau Corridor of Tsavo has different land-use types and is situated between two major protected areas.

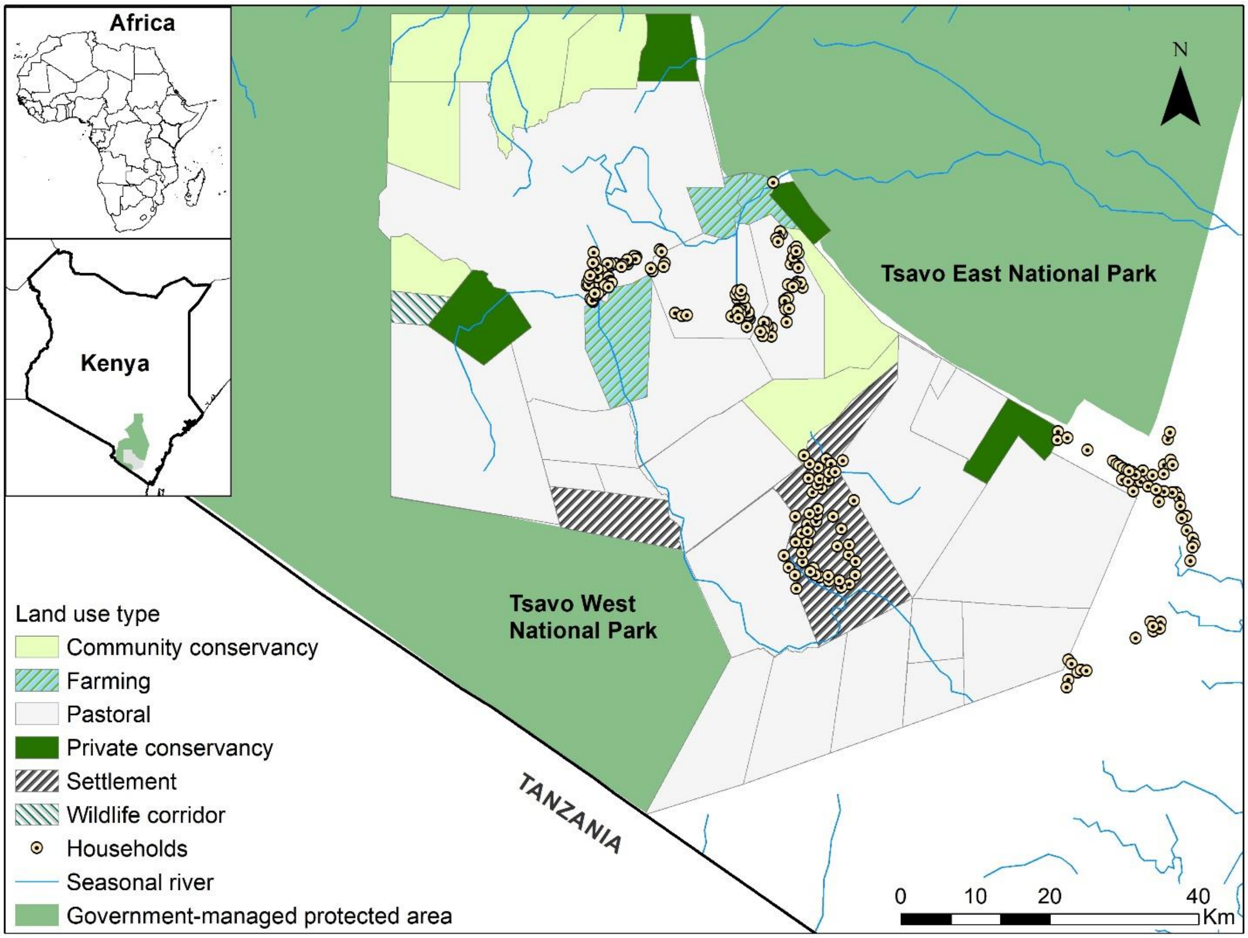

Figure 4.2.

Wildlife species that posed risks to human security and private property to respondents in Tsavo, southern Kenya. Responses were obtained from 331 households in which at least one member had experienced risks posed by wildlife in the local area.

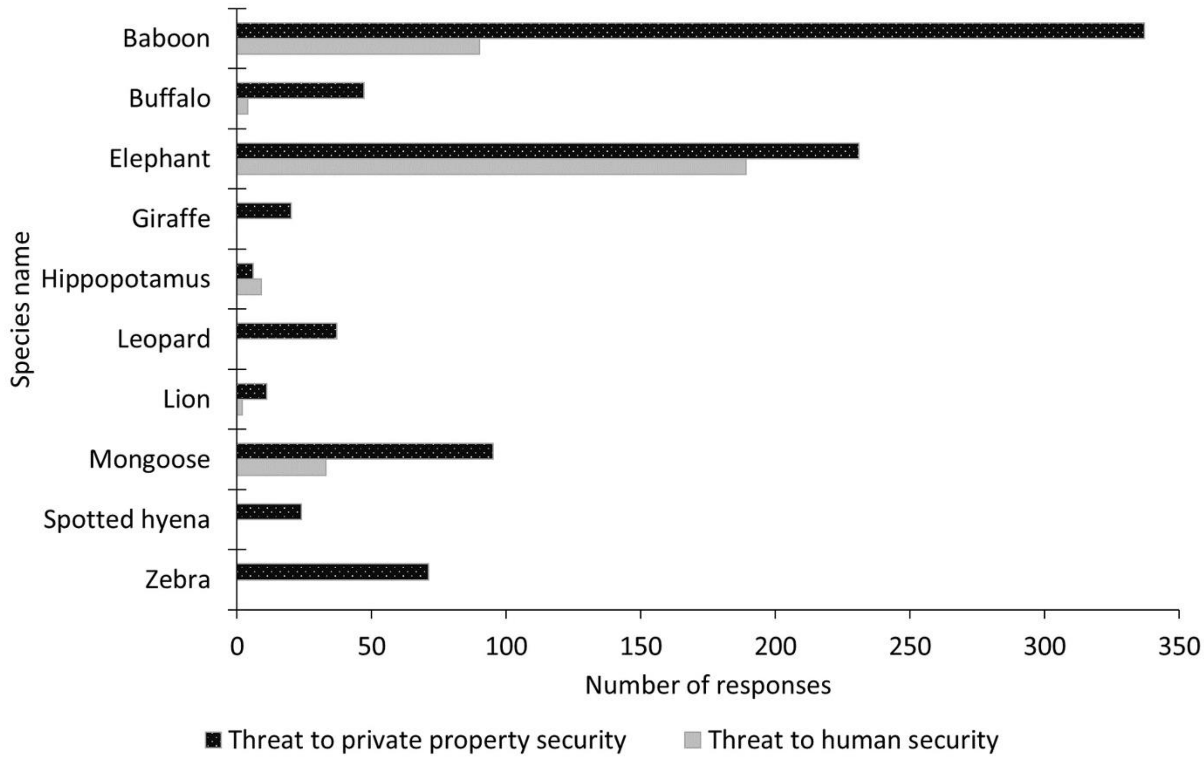

Figure 4.3.

Aftermath of a large carnivore attack in Tsavo, where depredation of livestock and crop damage can be devastating for pastoralists and smallholder farmers. Agropastoralism is an important source of income in Tsavo. © Wildlife Works.

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CONCLUSION

My research was motivated by recent declines of wildlife populations documented across East Africa (Ogutu et al. 2009, 2016). As such, this research covered two aspects of giraffe conservation that are also relevant to the protection of other wildlife species. Diseases and human activities play an important role in modulating population trends of wildlife (Daszak et al. 2000, Skerratt et al. 2007, Duporge et al. 2020). In Chapter One, I categorized GSD severity and found that the disease was more severe in Ruaha National Park compared to Serengeti National Park. Importantly, my study demonstrated that camera trap images and digital photos were a very useful platform for examining severity of skin disorders. In Chapter Two, I found marginal evidence of a positive correlation between giraffes with severe GSD and occurrence of lion marks. These results showed that GSD severity had a minor role in changing the likelihood of giraffes surviving lion predation attempts. In Chapter Three, I found that giraffe body parts mostly had consumptive and trophy uses, and three socioeconomic variables, specifically gender (male), occupation (tourism worker), and land ownership, were positively and significantly correlated with giraffe parts use. In Chapter Four, my research showed that people who had experienced risks to human security and private property posed by wildlife desired wildlife populations to decrease whereas respondents who did not have access to grazing lands for their livestock were inclined to see wildlife population grow.

My study presents novel findings that are broadly applicable for a variety of species and illustrates the need for contextualizing human heritage-centered conservation. First, my analytical framework involving photogrammetric techniques was shown to be suitable for species that can be individually identified using coat patterns and those that have externally presenting diseases (Karimuribo et al. 2011). Additionally, these techniques can be used on high-speed videos to assess impacts of skin diseases on the gait of afflicted animals (Bernstein-Kurtycz et al. 2021). These assessments, in combination with focal animal observations, can be provide tools to better assess impacts of skin diseases on wildlife. Future research should also be centered on identifying the specific etiological agent that causes GSD. My research only considered the external manifestations of GSD to assess severity. As such, pathophysiological analysis will be needed to fully understand and mitigate effects of GSD. This is particularly important considering that preliminary studies have identified filarial worms as potential etiological agents (Mpanduji et al. 2011, Epaphras et al. 2012), but these nematodes have also been linked with diseases in livestock (Schade et al. 2019). Given the high degree of overlap between giraffe ranges and community lands, identifying the causative agent of GSD and potential treatments should be a high priority.

While I found that GSD did not greatly impact the likelihood of giraffes surviving lion predation attempts, additional studies should seek to document other GSD-induced behaviours and physiological changes that may influence giraffe-lion interactions. My research in Ruaha was conducted over a four-month period, and future studies should observe giraffes over an extended period of time. Previous research has suggested that GSD severity increases during the rainy season in Ruaha (March – April) (Epaphras et al. 2012), but my study was conducted exactly between the wet and dry (September – December) seasons. As such, future studies examining correlations between environmental conditions, GSD severity and lion-giraffe interactions could broaden our understanding of potential impacts of the disease. Giraffes in Ruaha National Park have GSD lesions on the forelegs (Muneza et al. 2016). Considering that there is variation in the manifestation of GSD across the range of giraffes (Muneza et al. 2016), additional research should focus on areas where lesions appear on different anatomical locations.

My research identified that there is use of giraffe parts in Kenya. However, additional studies are necessary to quantify the extent to which poaching has affected the trend of giraffe populations. Such studies should also include other wildlife species considering that bushmeat has been found in local butcheries disguised as livestock meat (Ouso et al. 2020). This suggests that individuals can purchase bushmeat either unwittingly or purposefully, which is illegal across many range states. Future studies can also document common trade routes, which would help in implementing mitigation efforts. My results also showed that attitudes towards wildlife have complex links to previous experience with risks to human security and private property and background conditions in the environment. Given that land use and tenure systems are changing (Kimiti et al. 2016, Greiner 2017), more robust studies can assess variations in people's attitudes toward wildlife in relation to socioeconomic factors. Additionally, my research showed that the spatial configuration of risks posed by wildlife plays an important role in influence attitudes. However, more robust analysis can elucidate this relationship and provide information that is pertinent to local communities. Lastly, my research techniques can be replicated in other regions of sub-Saharan Africa, where skin diseases and conflicts with wildlife have been recorded.

APPENDIX

APPENDIX

Figure 5.1.
Questionnaire used to interview respondents during the research examining giraffe parts use and risks to human security and private property in Tsavo Conservation Area, southern Kenya

PARTICIPANT CONSENT FORM

You are being asked to participate in a research study examining the socioeconomic and cultural factors that affect giraffe populations in your community.

Your participation in the study will consist of giving us permission to ask you a maximum of 55 questions relating to giraffe ecology, diseases, and interactions with humans in your community. We intend to use this research to document the socioeconomic and cultural values of giraffe and make recommendations pertaining to their conservation. The entire survey will take about one hour.

All data will be treated with strict confidence, and your name will not be used in any report of the research findings. Your participation in this study is confidential and anonymous. Your privacy will be protected to the maximum extent allowable by law. If you would want to know the results of the study (within these restrictions) you should leave your contact details with us.

There is no cost or compensation offered to participate. Thus, your participation is completely voluntary. You have complete freedom to discontinue the study at any time without penalty. If at any point you feel any discomfort with the questions, please do not hesitate to stop the survey. You have complete freedom to discontinue the study at any time.

Your decision to participate or not participate in the research will have no effect on your relationship with colleagues at Michigan State University, the Giraffe Conservation Foundation or community members. If you have concerns or questions about this study, such as scientific issues or how to do any part of it, please contact the researcher:

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If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research

Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, MSU, East Lansing, MI 48824.

Participant's consent: Yes ________________ No ______________________

Quality Check

______ Survey Complete

______ Questionnaire number on each page

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Waypoint number: ________________

Questionnaire number: ____________

Questionnaire number: ____________________ Date (D/M/Y): _____________________

HUMAN DIMENSIONS OF WILDLIFE QUESTIONNAIRE

Wildlife populations across East Africa face various threats, among them human-wildlife conflict. This study seeks to understand the various social, cultural, and economic factors that influence interactions between humans and wildlife, with a particular focus on giraffe populations in southern Kenya.

SECTION 1: WILDLIFE-RELATED ACTIVITIES AND INTERACTIONS IN YOUR VILLAGE

1A. Please indicate which, if any, of the following types of interactions you, a member of your household or someone you know have ever had with wildlife? (Choose ALL that apply)

	Species	Observed / Seen tracks	Threatened	Crops / livestock destroyed	Person injured / killed	Livestock injured / killed	Wildlife killed by management	Other
a1	Baboon (Nyani)							
a2	Buffalo (Nyati)							
a3	Cheetah (Duma)							
a4	Elephant (Ndovu)							
a5	Giraffe (Twiga)							
a6	Hippopotamus (Kiboko)							
a7	Hyena (Fisi)							
a8	Leopard (Chui)							
a9	Lion (Simba)							
a10	Wildebeest (Nyumbu/Gnou)							
a11	Zebra (Punda milia)							
a12	Mongoose (Kicheche)							
a13	Other:							
a14	Other:							
a15	Other:							

1B. When thinking about the species that might threaten (chase after) or attack (injure or kill) your livestock, what is your first reaction?

Questionnaire number: _________________ Date (D/M/Y): ____________________

	Species responsible	Nothing		Report to local leader		Report to park / police authorities		Mobilize locals to chase it away		Mobilize locals to kill animal	
		Threaten	Attack	Threaten	Attack	Threaten	Attack	Threaten	Attack	Threaten	Attack
b1	Baboon (Nyani)										
b2	Buffalo (Nyati)										
b3	Cheetah (Duma)										
b4	Elephant (Ndovu)										
b5	Giraffe (Twiga)										
b6	Hippopotamus (Kiboko)										
b7	Hyena (Fisi)										
b8	Leopard (Chui)										
b9	Lion (Simba)										
b10	Wildebeest (Nyumbu)										
b11	Zebra (Punda milia)										
b12	Mongoose (Kicheche)										
b13	Other:										
b14	Other:										
b15	Other:										

1C. When thinking about the species that might threaten (chase after) or attack (injure or kill) people, what is your first reaction?

Questionnaire number: ___________________ Date (D/M/Y): ______________________

	Species responsible	Nothing		Report to local leader		Report to park / police authorities		Mobilize locals to chase it away		Mobilize locals to kill animal	
		Threaten	Attack	Threaten	Attack	Threaten	Attack	Threaten	Attack	Threaten	Attack
c1	Baboon (Nyani)										
c2	Buffalo (Nyati)										
c3	Cheetah (Duma)										
c4	Elephant (Ndovu)										
c5	Giraffe (Twiga)										
c6	Hippopotamus (Kiboko)										
c7	Hyena (Fisi)										
c8	Leopard (Chui)										
c9	Lion (Simba)										
c10	Wildebeest (Nyumbu)										
c11	Zebra (Punda milia)										
c12	Mongoose (Kicheche)										
c13	Other:										
c14	Other:										
c15	Other:										

1D. When you experience problems with wildlife in your community, who normally deals with these issues?

Use 1-community members; 2-County government; 3-KWS; 4-National government; 5-Community scouts; 6-No one; 7-Do not know; 8-Other (indicate name)

d1	Crop damage by wildlife	
d2	Illegal trafficking and killing of wildlife	
d3	Land demarcation	
d4	Use of communal resources by people from outside the community	
d5	Land dispute between two community members	
d6	Land dispute between communities	

Questionnaire number: ____________________ Date (D/M/Y): _____________________

1E. Which of the wild animals listed above (1B) are your two most favourite? Please state why that animal is your most favourite.

Write animal and reason given in the spaces below.

e1	1.	
e2	2.	

1F. Which of the wild animals listed above (1B) are your two least favourite? Please state why that animal is your least favourite.

Write animal and reason given in the spaces below.

f1	1.	
f2	2.	

1G. To what extent do you agree or disagree (as you feel in the present) with the following statements?

	Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	No response
g1	1. Eating wild meat in this community is healthier for you than eating farmed meat						
g2	2. Wild animals in this community are used for medicinal purposes						
g3	3. Wild meat in this community is an important part of my culture						
g4	4. I would be happy if wild animal meat for consumption was easier to find in this community						
g5	5. This community would be better if wild animals remained in places far from human settlements						

Questionnaire number: ________________ Date (D/M/Y): ___________________

g6	6. I have no problem with wild animals being killed for meat/food for people in this village						
g7	7. It is possible to live in a world where people can coexist in harmony with wildlife						
g8	8. I like that there are wild animals in this area						
g9	9. I feel a strong emotional bond with wild animals						
g10	10. Eating wild animal meat in this area is causing population declines of wildlife						

SECTION 2. GENERAL ATTITUDES TOWARDS WILDLIFE IN YOUR VILLAGE

2A. How has the population (numbers of animals) of the following wildlife species in your village changed during the past five years? (Choose only ONE option for each species)

	Species	Decreased greatly	Decreased somewhat	Remained about the same	Increased somewhat	Increased greatly	Do not know
2.a1	Baboon (Nyani)						
2.a2	Buffalo (Nyati)						
2.a3	Cheetah (Duma)						
2.a4	Elephant (Ndovu)						
2.a5	Giraffe (Twiga)						
2.a6	Hippopotamus (Kiboko)						
2.a7	Hyena (Fisi)						
2.a8	Leopard (Chui)						
2.a9	Lion (Simba)						
2.a10	Wildebeest (Nyumbu)						
2.a11	Zebra (Punda milia)						
2.a12	Mongoose (Kicheche)						
2.a13	Other:						
2.a14	Other:						
2.a15	Other:						
2.a16	All wildlife in general						

Questionnaire number: ________________ Date (D/M/Y): ____________________

2B. To what extent do the following problems affect you? Please tick one box in each row.

	Threat	Not at all	A little	A lot	Do not know
2.b1	1. Drought				
2.b2	2. Land degradation				
2.b3	3. Animal or crop diseases				
2.b4	4. Conflicts with wildlife				
2.b5	5. Conflicts with local leaders				
2.b6	6. Conflicts with government officials				
2.b7	7. Conflicts with neighbouring communities				
2.b8	8. Access to grazing/land				
2.b9	9. Access to water				
2.b10	10. Other______________________________				

2C. To what extend do you agree with the following statements relating to wildlife interactions in your village/household

Reponses are coded as (-2) strongly disagree, (-1) disagree, (0) Neither Agree or Disagree, (+1) agree, and (+2) strongly agree for analysis.

	Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	No response
2.c1	1. Interactions between wildlife and people is something new and novel in my village						
2.c2	2. Member(s) of my household are at risk from wildlife in the villages that I live, work, or recreate						
2.c3	3. All the risks associated with living with wildlife are well understood by the wildlife managers and experts						

Questionnaire number: ________________ Date (D/M/Y): ___________________

2.c4	4. My household can live with crop or livestock damage associated with wildlife over time						
2.c5	5. My household can live with the risk of being threatened or injured associated with wildlife over time						
2.c6	6. My household can live with the risk to health or death associated with wildlife with over time						
2.c7	7. My livestock can cope with the risk of contracting diseases from wildlife						
2.c8	8. My community has a good working relationship with the park authorities						
2.c9	9. The people who benefit from wildlife in the park are the same people who are exposed to the potential risks of living with wildlife						

2D. Would you like the following wildlife populations in your village to increase, decrease or remain at its current level over the next five years. (please choose ONLY ONE option for each species)

	Species	Decrease greatly	Decrease somewhat	Remain at current level	Increase somewhat	Increase greatly	No Opinion
2.d1	Baboon (Nyani)						
2.d2	Buffalo (Nyati)						
2.d3	Cheetah (Duma)						
2.d4	Elephant (Ndovu)						
2.d5	Giraffe (Twiga)						
2.d6	Hippopotamus (Kiboko)						
2.d7	Hyena (Fisi)						
2.d8	Leopard (Chui)						
2.d9	Lion (Simba)						
2.d10	Wildebeest (Nyumbu)						
2.d11	Zebra (Punda milia)						
2.d12	Mongoose (Kicheche)						

Questionnaire number: __________________ Date (D/M/Y): _____________________

2.d13	Other:							
2.d14	Other:							
2.d15	Other:							
2.d16	All wildlife in general							

2E. (i) Do you or anyone in your household hunt wildlife? Yes [ ] No [ ]

(ii) If yes, what tools/methods are used for hunting animals in your household? Check all that apply.

(iii) If you do not employ a certain method, please indicate why you do not use the method.

Fill up all gaps in this table. For each species and tool, answer can be: (NA) Not acceptable, (NO) No opinion, (U) Unaffordable, (I) Inaccessible, (IE) inefficient, (D) Do not know how to use

	Species	Bow and arrow	Wire snare	Spear	Pitfall trap	Guns	Panga (and bright light)	Other
2.e1	Baboon (Nyani)							
2.e2	Buffalo (Nyati)							
2.e3	Cheetah (Duma)							
2.e4	Elephant (Ndovu)							
2.e5	Giraffe (Twiga)							
2.e6	Hippopotamus (Kiboko)							
2.e7	Hyena (Fisi)							
2.e8	Leopard (Chui)							
2.e9	Lion (Simba)							
2.e10	Wildebeest (Nyumbu)							
2.e11	Zebra (Punda milia)							
2.e12	Mongoose (Kicheche)							
2.e13	Other:							
2.e14	Other:							
2.e15	Other:							
2.e16	All wildlife in general							

Questionnaire number: ____________________ Date (D/M/Y): _____________________

SECTION 3. INTERACTIONS WITH GIRAFFE POPULATIONS IN YOUR AREA

3A. Which best describes your feelings (at present) towards the giraffe that live in your area? We would like to know how much you like or dislike (Tick only one)

Strongly dislike	[ ]
Dislike	[ ]
Neutral	[ ]
Like	[ ]
Strongly Like	[ ]
No response	[ ]

3B. How important is it for giraffe to live in your area? (Tick only one)

Not important	[ ]
A little important	[ ]
Very important	[ ]
Do not know	[ ]

3C. When you see giraffes, what are they most often doing?

____

____

____

3D. In which time of the year are there more giraffes in your area?

____

3E. In which areas do you see giraffes most often in your region?

3.e1	Forest (Porini)	[ ]
3.e2	Savannah (Grassland/Nyika)	[ ]
3.e3	Near water	[ ]
3.e4	Village land	[ ]

3F. In which areas do you never see giraffes in your region?

3.f1	Forest (Porini)	[ ]
3.f2	Savannah (Grassland/Nyika)	[ ]
3.f3	Near water	[ ]
3.f4	Village land	[ ]

Questionnaire number: __________________ Date (D/M/Y): _____________________

3G. For each of the following, please tell us whether or not you receive that benefit from having giraffe in this community.

		Yes	No	I do not know
3.g1	a. Money from tourists coming to see them			
3.g2	b. Job in tourism/conservation			
3.g3	c. I enjoy seeing them			
3.g4	d. Meat or other parts of the giraffe			
3.g5	e. Helps with crops			
3.g6	f. Helps with livestock			
3.g7	g. Helps with the working of the savanna			
3.g8	h. Has cultural importance			
3.g9	i. Any other benefits from giraffe we have not said already? Write brief answer below.			

3H. (i) Have you or anyone in your household used meat or other parts of a giraffe? Yes [ ] No [ ]

If no, skip to Question 3I.

(ii) If yes, when was the most recent time you used giraffe meat or other parts of giraffe? Please tick one box.

Within the last 12 months [ ]
Between 1-5 years ago [ ]
Between 6-10 years ago [ ]
More than 10 years ago [ ]

(iii) How often have you used giraffe parts or products in your lifetime? Please circle one below

1-10 times 11-20 times 21-30 times more than 30 times

Questionnaire number: __________________ Date (D/M/Y): _____________________

(iv) If you have used giraffe parts or products at least once in your lifetime, please indicate the part and type of utilization:

	Type of utilization	Bone	Bone marrow	Meat	Skin	Tail	Hair	Skull	Other
3.iv.h1	Consumption								
3.iv.h2	Traditional medicine								
3.iv.h3	Cultural use and decoration (symbolism / jewellery)								
3.iv.h4	Fly-whisk								
3.iv.h5	Trade								
3.iv.h6	Other:								
3.iv.h7	Other:								
3.iv.h8	Other:								
3.iv.h9	Other:								

(v) If you have used giraffe parts or products at least once in your lifetime, please indicate how/where you acquired the product and (or) if you know the indicative estimate cost in your area

	Part	Widely-known market area		Widely-known supplier		One-time supplier		Yourself [Hunting] (selling price)		Opportunistic		Other	
		Y/N	Cost	Y/N	Cost	Y/N	Cost	Y/N	Cost	Y/N	Cost	Y/N	Cost
3.v.h1	Bone												
3.v.h2	Bone marrow												
3.v.h3	Meat												
3.v.h4	Skin												
3.v.h5	Hair												
3.v.h6	Tail												
3.v.h7	Skull												
3.v.h8	Other:												
3.v.h9	Other:												
3.v.h10	Other:												

Questionnaire number: ___________________ Date (D/M/Y): ____________________

3I. If you used to hunt or trap giraffes and no longer do, what is the reason you stopped?

3.i1 Affordability of tools [ ]
3.i2 Cannot sell products/parts [ ]
3.i3 Very low prices [ ]
3.i4 Government laws [ ]
3.i5 Community rules [ ]
3.i6 I have no interest [ ]
3.i7 Found alternative source of income [ ]
3.i8 No longer found in my area/Have to travel far [ ]
3.i9 Other: ____

3J. i) Have you seen giraffes with skin diseases? Yes No (circle one) Please refer to accompanying photos.

ii) Are giraffe with skin diseases a threat to you? Yes No (circle one)

iii) Are giraffe with skin diseases a threat to your livestock? Yes No (circle one)

iv) Are emaciated (or sick-looking) giraffe a threat to you or your livestock? Yes No

3K. i) Have you heard of giraffes being killed by a human? Yes No (circle one)

ii) Have you heard of humans being killed by a giraffe? Yes No (circle one)

iii) If at least one answer from the above is yes, when and where did said incident happen?

	Timeline	In this community		Outside of this community	
		Giraffe death	Human death	Giraffe death	Human death
3.iii.k1	<1 month				
3.iii.k2	1 – 6 months				
3.iii.k3	6 – 12 months				
3.iii.k4	More than a year				

iv) How was the giraffe killed by a human? Please tick all that apply.

3.iv.k1 I do not know [ ]
3.iv.k2 Bow and arrow [ ]
3.iv.k3 Panga [ ]
3.iv.k4 Gun [ ]
3.iv.k5 Snare [ ]
3.iv.k6 Spear [ ]
3.iv.k7 Poison [ ]
3.iv.k8 Other: ____

Questionnaire number: ____________________ Date (D/M/Y): _____________________

SECTION 4. DEMOGRAPHICS

4A. Sex of respondent?

Female [ ]
Male [ ]

4B. Respondent's main occupation: please tick one.

Livestock herder/pastoralist [ ]
Crop farmer [ ]
Tourism worker [ ]
Business owner [ ]
Other employment: ___________________________________

4C. Please state monthly income: ________________________

4D. In the last year, has your household income change?

Has not changed [ ]
Decreased [ ]
Increased [ ]
Do not know [ ]

4E. Were you born here or in a different community?

Here [ ]
A different community [ ]
Name of community: __________________________________

4F. If from a different community, since when have you lived in the current area?

____

4G. Do you own land in your current area? If yes, how big is the land?

____

4H. Do you solely own exclusively own the land or is it part of a community ranch/conservancy/sanctuary? __________________________

4I. What is your age? _____________________________________

Questionnaire number: ____________________ Date (D/M/Y): _____________________

4J. What is your highest level of completed education?

None [ ]
Primary [ ]
Secondary [ ]
College [ ]
University [ ]
No response [ ]

4K. How many people currently live in your household?

Adults (Over 18 years) ____________
Children (Under 18 years) ____________

4L. (i) Have you or a member of your household ever been inside the national park?

No [ ] Yes [ ]

(ii) How long ago? ____

(iii) Via what means? ____

4M. What type of fuel is most often used for cooking?

Wood [ ] Source:____
Cylinder gas [ ] Source:____
Kerosene [ ] Source:____
Charcoal [ ] Source:____
Other: ____

4N. What is the primary source of lighting for your household?

Electricity [ ]
Oil/Kerosene lamp [ ]
Candle [ ]
Solar panel [ ]
Personal electric generator [ ]
Other: ____

4O. What is the primary source of your drinking/cooking water?

Pipe water [ ]
Personal/family Borehole [ ]
Communal well [ ]

Questionnaire number: ____________________ Date (D/M/Y): _____________________

Neighbour's well [ ]
Lake/river/stream [ ]
Rain water [ ]
Other: ____

4P. Approximately what percentage of your household's food comes from the following sources now compared to a year ago? Columns should add up to 100%

		This year	Last year
4.p1	Percentage from own farm		
4.p2	Percentage from local markets		
4.p3	Percentage from local stores		
4.p4	Percentage from outside vendors		
4.p5	Other:		
4.p6	Total		

4Q. Please tell us about the changes happening in your community.

		A. On a scale where 1 means "none" and 5 means "a lot", how much are the following changes occurring in your community? 1-None; 2-A little; 3-Some; 4-A moderate amount; 5-A lot	B. On a scale where 1 means "very negative" and 5 means "very positive", how do you feel about these changes? 1-Very negative; 2-Negative; 3-Neutral; 4-Positive; 5-Very positive
4.q1	Access or connection to places to buy goods outside your community		
4.q2	People moving into your community		
4.q3	People moving out of your community		
4.q4	New technologies coming into your community		

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REFERENCES

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