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MITIGATION OF HUMAN-WILDLIFE-CONFLICT IN MASAI MARA, KENYA

MITIGACIÓN DEL CONFLICTO ENTRE HUMANOS Y LA VIDA SALVAJE EN MASAI MARA, KENIA

PRESENTADA POR:

D. DOMNIC MIJELE OTIENO

DIRIGIDA POR:

DR. D. SAMER ANGELONE-ALASAAD

DR. D. RAMÓN C. SORIGUER

DR. D. ANTONIO SÁNCHEZ BACA

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Chapter 1: Introduction justification and research approach

This thesis is concerned with human wildlife conflict and its management in the Masai Mara area of Kenya. Human wildlife conflict is defined as any negative interaction between humans and wild animals. It involves human death and injuries, damage to property, and disease transmission to humans and their livestock caused by wildlife. It also involves human inflicted mortality and injuries to wildlife.

Human-Elephant Conflict

In the Masai Mara ecosystem we examined aspects of human elephant conflict and its management. In addition we also focused on the risk of parasite transmission from wildlife to domestic animals and vice versa. Human-elephant conflict (HEC) is a chronic problem that occurs wherever elephants and people share habitat. It is a major threat to the long term survival of the African elephant. HEC can be defined generically as ''any human-elephant interaction which results in negative effects on human social, economic or cultural life, on elephant conservation or on the environment'' (Parker et al., 2007). Even so, most studies are focused on the first premise of this definition, that is, the negative effects on human socio-economic and cultural life (Sitati et al., 2003) and little is known of the negative effect of these conflicts on elephant conservation (Sitati et al., 2003). HEC is a problem that poses serious challenges to wildlife managers, local communities and elephants alike (Sitati et al., 2003) and occurs throughout the species' range in Africa. This study focused on the spatio-temporal distribution of injured elephants due to HEC in Masai Mara and the putative negative and positive roles of the local community therein. The main factor affecting the spatio-temporal prevalence of elephant injuries is probably the seasonality of elephant movements and their relationship with local community settlements, farms, rivers and roads.

The close interaction between people and wildlife have led to increased human-elephant conflicts within this animal's dispersal areas and farmers and pastoralists alike respond by scaring elephants away from their farms and settlements using traditional weapons such as arrows and spears that usually cause physical injuries to elephants. Some of these injuries are quite severe and if not treated can lead to the death or deformity of an elephant and can have a real effect on elephant populations in long term.

Due to the severe and complex consequences of HEC, it is important to understand the factors that underpin the spatial occurrence of cases of human inflicted injuries to elephants in order to be able to formulate pragmatic mitigating responses.

There are two main approaches to alleviating HEC: controlling elephant numbers and expanding elephant range (Pinter-Wollman, 2012: Van Aarde & Jackson, 2007). Elephant numbers may be controlled by translocation, culling and contraceptives, while the establishment of frontier parks and wildlife corridors expands elephant ranges. Several methods to mitigate HEC have been suggested and some have been applied with varying success, however, no single approach is sufficient as a universal solution for conflict alleviation (Sitati et al., 2003). Elephant translocation has been carried out in various parts of Kenya over a period of time as a way of mitigating HEC with varied outcomes as highlighted in the next chapter of this thesis.

Elephant translocation

In this thesis, we review the outcome of elephant translocation carried out by Kenya Wildlife Service (KWS) between 1995 and 2012 to mitigate HEC. We describe step-by-step translocation procedures that include the number of elephants moved, their sexes and age groups, reason behind translocation decision, translocation distance, and economic cost among other experiences. This paper will help to guide the future decision-making on use of translocation in mitigating HEC in Kenya and other places across elephant ranges.

Migratory wildebeest parasites and livestock

Human wildlife conflict can also result into parasites or disease transmission from wildlife to humans and their livestock or vice versa.

Long distance migration, common in several species of birds, butterflies and mammals can affect the prevalence, diversity and burden of parasites and pathogens in migratory populations of these species. Although parasite prevalence and diversity is known to occur in many populations of migratory species particularly birds and butterflies, very little is known regarding parasite prevalence and diversity in migratory populations of many mammalian species particularly the blue wildebeest (*Connochaetes taurinus*).

Over a million blue wildebeests are known to migrate annually from Serengeti in Tanzania to Masai Mara in Kenya covering approximately 3,000 km in search of adequate pasture and water. During the migration period, wildebeests come into contact with various parasite or pathogen faunas, characteristic of different geographical areas and habitats in their migration routes (Alerstam et al., 2003). They also come into contact with many livestock and other resident wildlife along their migratory routes. The parasite faunas of non-migratory wildebeest are well documented (Horak et al., 1983) but nothing is known about the parasites of migratory wildebeest.

Currently, insights into host–parasite interactions are still largely based on studies involving single parasite strains infecting single hosts. Yet, in the real world, hosts are often infected by numerous parasite genotypes of the same or different species simultaneously (Ulrich and Schmid-Hempel, 2012).

Since migratory wildebeests are likely to harbor multiple helminthes infections and fresh carcasses were available from annual natural deaths, they provided an opportunity to investigate the epidemiology of the most common gastrointestinal parasites and parasite predilection and co-infection patterns within hosts. These patterns may help reveal parasite interactions like competition for host resources or attachment sites within the host (Cattadori et al., 2007, Mideo, 2009) or interactions between parasites and the host's immune system and possible transmission to livestock.

Research objectives

1. What is the extent of active and passive injuries on elephants inflicted by local communities in the Masai Mara ecosystem?

2. Do elephant age and sex influence patterns of elephant injuries?

3. How is the spatio-temporal distribution of injured elephants in relation to human settlements, roads, rivers and crop farms?

4. How do local communities negatively affect elephants by their use of snares to capture other wild animals as bush meat?

5. What are the positive roles of local communities as key informants in the early detection of injured elephants?

6. How effective is the elephant translocation as one of the tools to mitigate HEC?

7. Has translocations achieved any significant decline in HEC cases in Kenya?

8. Do wildebeests face a greater risk of acquiring helminths from livestock in pastoralist dominated landscapes during migration or do they transmit parasites to livestock in the migratory corridors?

9. Does age have effect on parasites load and co-infection in migratory wildebeests?

10. How do the predilection gastrointestinal sites chosen by helminth parasites in migratory wildebeests compared to sites occupied in domestic ruminants and what are the significance of this?

11. Does sex have effect on the prevalence of helminth parasites found in the migratory wildebeests?

12. Does the duration of migration process affect parasite charge in migratory wildebeests?

Capítulo 1: Introducción, justificación y enfoque de la investigación

Esta Tesis concierne al conflicto suscitado entre los humanos y la fauna y su gestión en el área de Masai Mara, Kenia. El conflicto humano-fauna es definido como una interacción negativa entre los humanos y la fauna. Implica la muerte, lesiones, daños a la propiedad, y la transmisión de enfermedades a los seres humanos y al ganado provocados por la fauna silvestre. Aunque de forma recíproca también se relaciona a los humano con lesiones y la mortalidad ocasionadas en la fauna.

El conflicto humano-elefante

En el ecosistema de Masai Mara examinamos aspectos del conflicto elefante-humano y su gestión. Además, nos hemos centrado en el riesgo de transmisión de parásitos de animales salvajes a los animales domésticos y viceversa. Los conflictos entre el hombre y el elefante (HEC) son un problema crónico que se produce cuando los elefantes y las personas comparten el hábitat. Es una de las principales amenazas para la supervivencia a largo plazo del elefante africano. HEC puede definirse genéricamente como "cualquier interacción hombre-elefante que produce efectos negativos sobre derechos sociales, económicos o culturales, la vida en la conservación de los elefantes o sobre el medio ambiente" (Parker et al., 2007). Aun así, la mayoría de los estudios se centran en la primera premisa de esta definición, es decir, los efectos negativos sobre la vida socio-económica y cultural (Sitati et al., 2003) y se sabe poco de los efectos negativos de estos conflictos sobre la conservación del elefante (Sitati et al., 2003). HEC es un problema que plantea serios retos tanto a gestores de fauna, comunidades locales como a elefantes (Sitati et al., 2003) y se produce en toda el área de distribución de la especie en África. Este estudio se centró en la distribución espacio-temporal de los elefantes heridos debido a la HEC en Masai Mara y el supuesto papel positivo y negativo de la comunidad local en ella. El principal factor que afecta a la prevalencia espacio-temporal de las lesiones producidas en el elefante es, probablemente, la estacionalidad de movimientos de los elefantes y su relación con la comunidad local de los asentamientos, granjas, ríos y carreteras.

La estrecha interacción entre la gente y la vida silvestre ha conducido a un aumento de los conflictos entre el hombre y el elefante dentro de las areas de dispersión del animal, tanto con agricultores como con pastores. Estos por su parte responden asustando a los elefantes fuera de sus granjas y asentamientos con armas tradicionales como flechas y lanzas que usualmente causan lesiones físicas a los elefantes. Algunas de estas lesiones son bastante graves y si no se tratan pueden provocar la muerte o deformidades del elefante y pueden tener un efecto real sobre las poblaciones de elefantes a largo plazo.

Debido a las graves y complejas consecuencias de HEC, es importante entender los factores que sustentan los daños infligidos sobre los elefantes por parte del hombre, a fin de poder formular respuestas de mitigación pragmática.

Hay dos enfoques principales para disminuir HEC: controlar el número de elefantes y ampliar el su área de distribución (Pinter-Wollman, 2012: Van Aarde &Amp; Jackson, 2007). El número de elefantes pueden ser controlados por translocación, sacrificio y anticonceptivos, aunque el establecimiento de corredores biológicos y zonas fronterizas amplía el área de distribución del elefante.

Varios métodos para reducir HEC han sido sugeridos y algunos han sido aplicados con éxito, sin embargo, no es suficiente un único enfoque como solución universal para la reducción de conflictos (Sitati et al., 2003). La translocación de elefantes se ha llevado a cabo en diversas partes de Kenia a lo largo de un período de tiempo como una forma de mitigar la HEC con resultados variables, como se plantea en el próximo capítulo de esta tesis.

Translocación de elefantes

En esta tesis, revisamos los resultados de la translocación de elefantes realizados por el Kenya Wildlife Service (KWS) entre 1995 y 2012 para mitigar HEC. Describimos paso a paso los procedimientos de translocación que incluyen el número de movimientos por parte de los elefantes, sus sexos y grupos de edad, la razón que hay detrás de la decisión de la translocación, distancia de la translocación y gasto económico entre otras experiencias. Este trabajo ayudará a orientar la toma de decisiones futuras sobre el uso de la translocación en la mitigación de HEC en Kenia y en otros lugares a través del área de distribución del elefante.

Los parásitos migratorios en ñúes y ganado

El conflicto entre humanos y vida salvaje también puede producirse por la presencia de parásitos o la transmisión de enfermedades establecidas entre animales salvajes a los seres humanos y su ganado o viceversa.

La migración de larga distancia, común en varias especies de aves, mariposas y mamíferos pueden afectar a la prevalencia, la diversidad y la carga parasitaria y patógenos en poblaciones migratorias de estas especies. Aunque la prevalencia del parásito y la diversidad del mismo ocurre en muchas poblaciones de las especies migratorias, especialmente en pájaros y mariposas, se sabe muy poco acerca de la prevalencia del parásito y la diversidad en poblaciones migratorias de muchas especies de mamíferos, en particular el ñu azul (*Connochaetes taurinus*).

Más de un millón de ñúes azules migran anualmente desde el Serengueti en Tanzania a Masai Mara en Kenia recorren aproximadamente 3.000 kilómetros en busca de agua y pastos adecuados. Durante el período de migración, los ñúes entran en contacto con diversos patógenos o parásitos, endémicos de las diferentes zonas geográficas y hábitats de migración (Alerstam et al., 2003). Sin embargo también se produce contacto con muchos otros parásitos de ganado y fauna silvestre a lo largo de sus rutas migratorias. Los parásitos localizados en ñúes no migratorios están bien documentados (Horak et al., 1983), pero no se sabe nada sobre los parásitos de los ñúes migratorios.

En la actualidad, las percepciones sobre las interacciones huésped-parásito se basan en gran medida en estudios con cepas de parásitos individuales que infectan solo a hospedadores individuales. Sin embargo, en el mundo real, los hospedadores son a menudo infectados simultáneamente por numerosos genotipos del parásito de la misma o de diferentes especies (Ulrich y Schmid-Hempel, 2012).

El hecho de que los ñúes migratorios sean capaces de albergar múltiples infecciones causadas por helmintos y la presencia de cadáveres frescos disponibles por mortalidad natural anual, proporciona una oportunidad para investigar la epidemiología de los parásitos gastrointestinales más comunes y patrones de preferencia y coinfección del parásito dentro de los hospedadores. Estos pueden ayudar a revelar las interacciones del parásito como competencia por los recursos o sitios de fijación en el hospedador (Cattadori et al., 2007, Mideo, 2009) o las interacciones entre parásitos y sistema inmune del hospedador, y por consiguiente posible transmisión al ganado.

Objetivos de la investigación

1. ¿Cuál es el grado de lesiones activas y pasivas en elefantes por las comunidades locales en el ecosistema Masai Mara?

2. ¿Los patrones de edad y sexo del elefante influyen en las lesiones del mismo?

3. ¿Cómo es la distribución espacio-temporal de elefantes heridos en relación con los asentamientos humanos, carreteras, ríos y granjas de cultivo?

4. ¿Cómo afectan negativamente las comunidades locales a los elefantes por el uso de trampas para capturar otros animales salvajes para la obtención de carne de monte?

5. ¿Cuáles son los aspectos positivos de las comunidades locales como informadores clave en la detección temprana de elefantes heridos?

6. ¿Cómo de efectiva es la translocación de elefantes como herramienta para mitigar la HEC?

7. ¿Han logrado las translocaciones alguna reducción significativa en los casos de HEC en Kenia?

8. ¿Durante la migración en paisajes predominantes de ganado pastoril, corren los ñúes un riesgo mayor de adquirir helmintos o, por el contrario, son ellos los que transmiten parásitos al ganado en los corredores migratorios?

9. ¿El factor edad tiene efecto sobre la carga parasitaria y la coinfección en ñúes migratorios?

10. ¿Cómo de predilectas son las zonas gastrointestinales elegidas por los helmintos parásitos en ñúes migratorios en relación a las zonas ocupadas en rumiantes domésticos? ¿cuál es el significado de esto?

11. ¿Tiene efecto el factor sexo sobre la prevalencia de helmintos parásitos en ñúes migratorios?

12. ¿Afecta la duración del proceso a la carga parasitaria en la migración en ñúes migratorios?

Chapter 2: Spatio-temporal distribution of injured elephants in Masai Mara and the putative negative and positive roles of the local community

Spatio-Temporal Distribution of Injured Elephants in Masai Mara and the Putative Negative and Positive Roles of the Local Community

Domnic Mijele[1]*, Vincent Obanda[1], Patrick Omondi[1], Ramo´n C. Soriguer[2], Francis Gakuya[1], Moses Otiende[1], Peter Hongo[1], Samer Alasaad[2,3]*

1 Kenya Wildlife Service, Nairobi, Kenya, 2 Estacio´n Biolo´gica de Don˜ana, Consejo Superior de Investigaciones Cientı´ficas (CSIC), Sevilla, Spain, 3 Institute of Evolutionary Biology and Environmental Studies (IEU), University of Zu¨rich, Zu¨rich, Switzerland

Abstract

Background: Very few studies have ever focused on the elephants that are wounded or killed as local communities attempt to scare these animals away from their settlements and farms, or on the cases in which local people take revenge after elephants have killed or injured humans. On the other hand, local communities live in close proximity to elephants and hence can play a positive role in elephant conservation by informing the authorities of the presence of injured elephants.

Methodology/Principal Findings: Between 2007 and 2011, 129 elephants were monitored in Masai Mara (Kenya), of which 54 had various types of active (intentionally caused) or passive (non-intentionally caused) injuries. Also studied were 75 random control samples of apparently unaffected animals. The observed active injuries were as expected biased by age, with adults suffering more harm; on the other hand, no such bias was observed in the case of passive injuries. Bias was also observed in elephant sex since more males than females were passively and actively injured. Cases of passive and active injuries in elephants were negatively related to the proximity to roads and farms; the distribution of injured elephants was not affected by the presence of either human settlements or water sources. Overall more elephants were actively injured during the dry season than the wet season as expected. Local communities play a positive role by informing KWS authorities of the presence of injured elephants and reported 43% of all cases of injured elephants.

Conclusions: Our results suggest that the negative effect of local communities on elephants could be predicted by elephant proximity to farms and roads. In addition, local communities may be able to play a more positive role in elephant conservation given that they are key informants in the early detection of injured elephants.

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* E-mail: dmijele@kws.go.ke (DM); sameralasaad@hotmail.com (SA)

Introduction

Human-elephant conflict (HEC) is a chronic problem that occurs wherever elephants and people share habitat. This conflict is considered by the IUCN Species Survival Commission's African Elephant Specialist Group (AfESG) as a major threat to the long-term survival of the African elephant. Human-elephant conflict can be defined generically as ''any human-elephant interaction which results in negative effects on human social, economic or cultural life, on elephant conservation or on the environment'' [1]. Even so, most studies are focused on the first premise of this definition, that is, the negative effects on human social, economic and cultural life [2] and little is known of the negative effect of these conflicts on elephant conservation [2]. HEC is a problem that poses serious challenges to wildlife managers, local commu-nities and elephants alike [2] and occurs throughout the species' range in Africa, both in forest ecosystems in west and central Africa [3] and savanna ecosystems in east and south Africa [4,5]. Local communities in Kenya usually live in close proximity to elephants and are able to observe rapidly the presence of injured elephants and report such cases to the authorities; these people can hence play an important role as key informants in cases of elephant injury and participate positively in HEC. We report here the findings of the first study of the spatio-temporal distribution of injured elephants in Masai Mara and the putative negative and positive roles of the local community therein.

HEC has become an increasingly significant issue as human populations have expanded and encroached upon elephant habitat [6,7]. Some of the major conflict areas in the Masai Mara ecosystem include the community group ranches around Masai Mara National Reserve such as Siana, Koiyaki, Lemek and Olderkessi-Naikarra and further north around Ntulele and Siyiapei [8].

Although the nature of the physical harm inflicted on free-ranging African elephants (Loxodanta africana) in Kenya is well documented [9], its spatio-temporal distribution and its relation-ship to human-elephant conflict has not been well studied. The main factor affecting the spatio-temporal prevalence of elephants is probably the seasonality of elephant movements and their relationship with local community settlements, farms, rivers and roads.

The Masai Mara ecosystem is home to the world famous Masai Mara National Reserve, which is characterized by intense human-wildlife-livestock interaction in the wildlife dispersal areas surrounding the Reserve [10]. The close interaction between people and wildlife have led to increased human-elephant conflicts within this animal's dispersal areas and farmers and pastoralists alike respond by scaring elephants away from their farms and settlements using traditional weapons such as arrows and spears that can cause physical injuries to elephants. Some of these injuries are quite severe and if not treated can lead to the death or deformity of an elephant; hence in the long-term these lesions can have a real effect on elephant populations.

Free-ranging elephants are monitored by the Kenya Wildlife Service (KWS) for the presence of injuries (physical wounds or death). Wherever an injured elephant is detected, the KWS veterinarians immediately treat the injury or, if necessary, remove the carcass of the dead animal [9]. These interventions are time-consuming and entail high economic costs incurred by the KWS that include transport, drugs, darting equipment and personnel. Due to the severe and complex consequences of HEC, it is important to understand the factors that underpin the spatial occurrence of cases of harmed elephants in order to be able to formulate pragmatic mitigating responses.

The aims of this study were (i) to analyse the spatio-temporal distribution of injured elephants in Masai Mara between 2007 and 2011 and its possible relation to seasonality and proximity to local communities' settlements, roads, rivers and farms, and (ii) to evaluate the possible positive role of local communities as key informants in the early detection of injured elephants.

Methods

Study Area Masai Mara Ecosystem

The Masai Mara ecosystem is located in southwest Kenya along the Kenya-Tanzania border (1u10'000 and 2u10'000 S, 34u14'500 and 36u10'000 E) [11]. The region is bounded by the Rift Valley to the east, the international border with Tanzania to the south, and the Siria Escarpment to the west. It includes the world-famous Masai Mara National Reserve (MMNR), a protected area for wildlife (about 1510 km^2) along the border with Tanzania that is essentially the northern continuation of the Tanzanian Serengeti National Park. The MMNR is surrounded by community-owned group ranches (4870 km^2), that act as wildlife dispersal areas in the north and east. Land uses on these ranches include traditional livestock pastoralism, wildlife conservation, tourism and a small amount of subsistence maize and wheat cultivation [11]. The Masai people living around MMNR depend on livestock for their livelihoods. Pastoral livestock farming (mainly goats, camels, cattle and sheep rearing) [12] is the dominant production system in this area, which is characterised by intensive wildlife-livestock-human interaction that includes the sharing of pasture and water. The Masai Mara ecosystem has dense populations of wildlife including large mammals such as African elephants, lions, leopards, African buffaloes, black rhinoceros, wildebeests and several antelope species. Rainfall in the Mara region is bimodal with a short rainfall period in November–December and a longer period in April–June. The long dry season spans July–October and the short dry season January–March. However, these seasons are not fixed and variations occur as the rains become less predictable [13].

Mean temperatures have risen in the Mara region in recent decades leading to progressive habitat desiccation [14]. In the period 1977–2009, this region also experienced severe recurrent droughts, the most noteworthy occurring in 1984, 1993, 1999–2000 [14], 2005–2006 and 2008–2009.

Injured Elephants

Injured elephants (54 cases) were immobilized and georeferenced using hand-held GPS [15,16] by KWS veterinarians for clinical treatment and biodata collection: age group, sex, georeference and the date of capture (Fig. 1). Elephants were classified by age as either sub-adult (,10 years) or adults ($10 years). The nature of the injury, possible causes and the parts of the body affected were also recorded for each elephant. Injured elephants were immobilized by darting using a combination of etorphine hydrochloride (M99*H* Norvatis South Africa (Pty Ltd/ (Edms) Bpk) and hyaluronidase at varying dosages depending on the age and sex of the injured elephant [15,16]. The 1.5–3 ml darts, attached to a 60-mm long and 2.2 mm plain Dan-inject needles, were remotely delivered by a Dan-inject (Denmark) long-range projector. Immobilized individuals were then examined for injuries and the corresponding data recorded. Injuries were treated using 10% hydrogen peroxide, anti-inflammatory drugs and tincture of iodine and oxytetracycline spray (depending on the extent and location of the injury). In addition, long-term antibiotics were administered intramuscularly. After treatment the anaesthesia was reversed by the intravenous administration of diprenorphine hydrochloride [15].

The injured elephants were grouped into two categories: (i) actively injured elephants that had been intentionally attacked by the local communities using poisoned arrows or similar sharp objects (30 elephants), or (ii) passively injured elephants, which had been non-intentionally injured by the local communities via snares placed to capture wild animals for consumption as bushmeat (20 elephants). A further four injured elephants were not included in the analyses because we were unable to determine whether their injuries were active or passive (Fig. 2).

The response to cases of elephant injury was rapid since there is a resident KWS veterinarian in Masai Mara employed to deal with such occurrences; as well, the injuries generally greatly weakened the elephants and affected and/or reduced their ability to move. The pain caused elephants to remain close to where they had sustained their injuries. The distance moved after being wounded is normally short and we assume that it did not affect the distribution pattern of injury cases.

Elephant Population Estimation

The distribution and population of healthy (non-injured) elephants in the Masai Mara ecosystem was estimated in 2010 from the total aerial counts described by Norton Griffins [17]. This involved the use of a fixed upper wing Cessna 182 four-seater aircraft. A Geographical Positioning System (GPS) was used for navigation and marking the locations of the elephants counted. The census was done at 1-km intervals in an east-west direction from a flying height of 100 m. Wherever large elephant herds were encountered, the aircraft circled the area to establish the exact herd size.

Besides the injured elephants, 75 non-injured, apparently healthy elephants were selected randomly from the study area for statistical analysis. All injured elephants were georeferenced using hand-held GPS and the coordinates were entered in an Arc-GIS to generate a spatial map. Human settlements, crop farms, rivers and roads in the study area were also mapped using an Arc-GIS. The distances between each elephant (either non-affected or passively or actively injured) and the nearest human settlement, crop farm, river and road were estimated (Fig. 1).

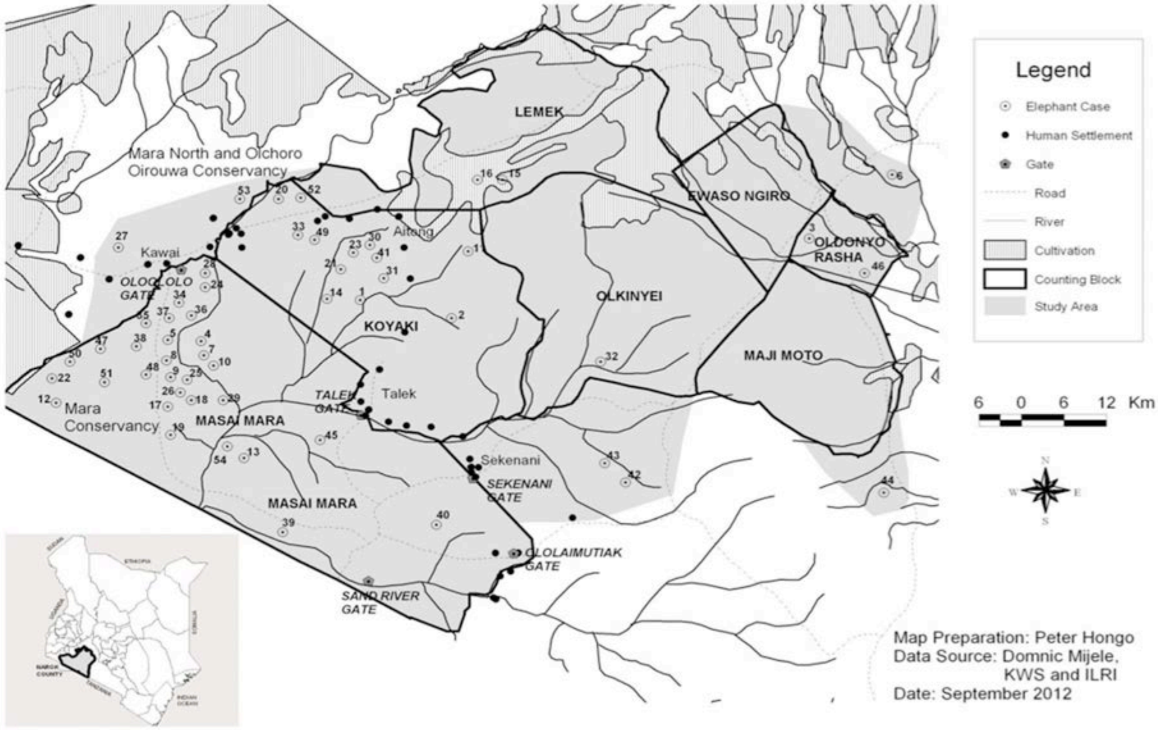

Figure 1. Spatial distribution of cases of elephant injury, rivers, roads, farmlands and human settlements in the Masai Mara ecosystem, Kenya.
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The calculation of the exact distribution of unaffected elephants in different periods (year and season) of our study was not possible. We assumed that the movement of elephants in Masai Mara is limited and that the snapshot sample that we carried out is representative of the rest of the study period.

Data Analyses

To estimate the possible effect of human settlements, crop farms, rivers and roads as possible risk factors affecting elephant status (unaffected, or passively or actively injured) we used a GLM Multinomial Logistic Regression. In the first Multinomial Model all possible variables (distances from human settlements, crop farms, rivers and roads) and their interactions were included. The response variable was elephant status (unaffected, or passively or actively injured). This full model was simplified step-by-step by deleting the non-significant variables or interactions. The criteria for simplifying the model were based on AIC criteria and an ANOVA analysis between the two models. Given that the data corresponding to unaffected elephants did not distinguish between sex, age class or season as possible risk factors (given that the location of each elephant was based on aerial counts), we performed a Logistic Regression Analysis with as the response variable only actively and passively injured elephants, and as explicatory variables the distance from human settlements, crop farms, rivers and roads, elephant sex and age class (adults or sub-adults), and season (dry or wet). The first Logistic Regression Model included all the explicatory variables and their interactions and the simplifying procedure was the same as for the Multinomial Model process. Fisher's Exact Test was applied to test the differences between season, sex and age class for actively and passively injured elephants. We did not consider crop-raiding reports from the communities around Mara in our analyses as a possible risk factor for elephant status since we had no appropriate systematic data; likewise, most cases of crop-raiding are not reported to the KWS and people merely chase elephants away, which sometimes get injured in the process, before they can raid crops. We used the R Package V.2.15.1 for all statistical analyses and figures.

Ethics

The study was approved by the ethics committee of the Kenya Wildlife Service (KWS) and the Government Department of Veterinary Services of Kenya. KWS guidelines on Wildlife Veterinary Practice-2006 were followed. All KWS veterinarians follow the Veterinary Surgeons and Veterinary Para-Professionals Act 2011, Laws of Kenya, which regulates veterinary practices in Kenya.

Results

In 2007–2011 in Masai Mara a total of 54 cases of injured elephants were detected and then examined and treated by a veterinarian. The injured elephants were classified into two categories: 60% (30/50) were actively injured elephants that had been intentionally attacked by local people with poisoned arrows or similar sharp objects, while 40% (20/50) were passively injured that had been non-intentionally injured by local people in snares placed to capture wild animals as bushmeat. Four other injured elephants were not included in the analyses because we were

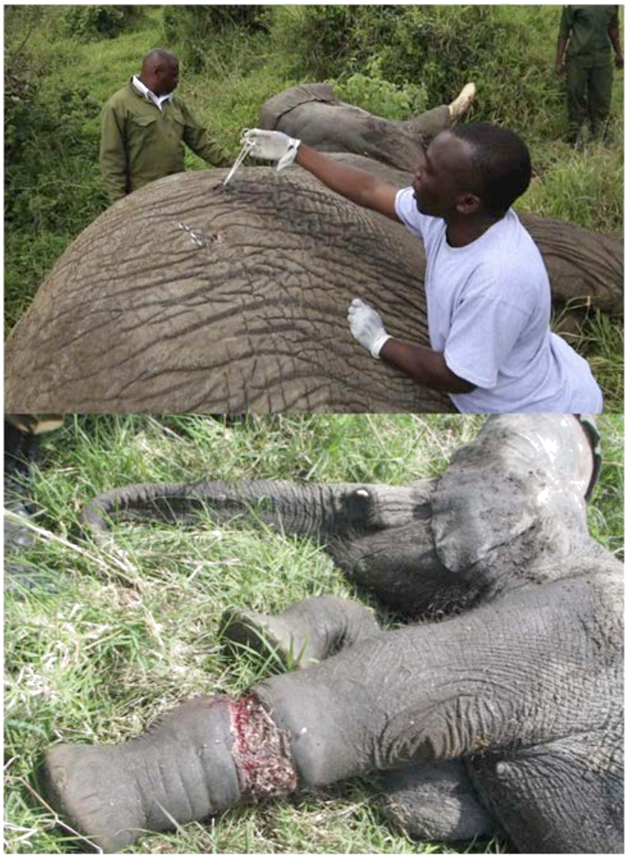

Figure 2. (Top) KWS vets treating an elephant actively injured with a poisoned arrow. (Below) A passively injured elephant in a snare. Masai Mara, Kenya. The two vets of the photograph have given written informed consent, as outlined in the PLOS consent form, to publication of their photograph.
doi:10.1371/journal.pone.0071179.g002

unable to ascertain the origin (active or passive) of their injuries (Fig. 2). There were no repeat injuries in our study.

Elephant limbs were the most vulnerable body part to injuries (Fig. 3). A Multinomial GLM indicated that road (p,0.015) and agriculture areas (p,0.001) had a negative effect on the health status of the elephants; on the other hand, neither human settlement nor water had any effect. The effect of agriculture areas and road had the same effect on passive and active injuries: the nearer the elephant to agriculture areas and road, the greater the possibility of being actively or passively attacked. The number of elephants with passive or active injuries increased in the proximity of agricultural areas and roads (Fig. 4).

The number of injured and healthy elephants was not significantly affected by the presence of water sources or human settlements. The selected Multinomial GLM was Injury (Active) , 0.9434 (60.6123) –0.5729(60.2077) LogAgriculture 20.4617(60.2098) LogRoad. Injury (Passive) , 20.2197 (60.7446) –0.2957(60.2460) LogAgriculture 20.3113 (60.2367) LogRoad.

When we considered only the injured (active and passive) groups, a GLM using the binomial model included only elephant age class as a significant variable (p = 0.020). Injury, 0.9651(60.4155) 21.2528(60.6059) Age.

Adult elephants were more vulnerable to actively inflicted injuries: 70% (21/30) were adults while only 30% (9/30) were sub-adults (p = 0.038). This was not the case of passively affected

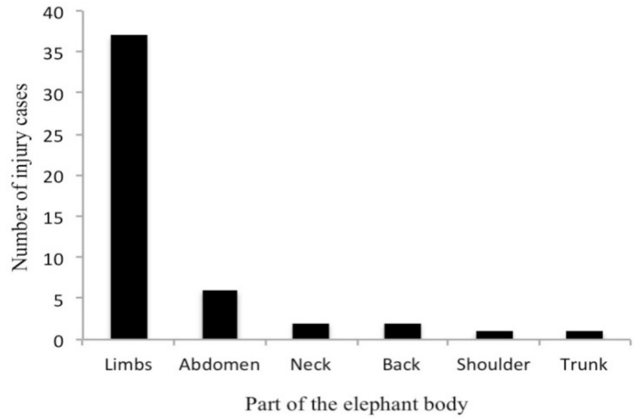

Figure 3. Number of injury cases involving different elephant body parts in 2007–2011 in the Maasa Mara, Kenya.
doi:10.1371/journal.pone.0071179.g003

elephants of which adults accounted for 40% (8/20) and sub-adults 60% (12/20).

Although not statistically supported (p = 0.55), males were proportionally more affected than females by passive injuries – 14 males (70%) and 6 females (30%) – and by active injuries –18 males (60%) and 12 females (40%).

The highest number of injury cases in elephants (n = 15) occurred in 2008 and 2011, while the least number of cases (n = 2) were detected in 2007. The post-mortem examination of freshly dead carcasses (n = 5) revealed gross pathologies associated with inflicted injuries.

There was seasonal variation in the number of actively injured elephants; more cases of actively injured elephants were detected in the dry season (19; 63%) than in the wet season (11; 37%), even though the difference was not statistically supported (p = 0.43). There were no differences between dry and wet (both 10; 50%) seasons (Fig. 5) in the number of passively affected elephants.

During the study period local communities reported 43% (23/54) of the injured elephants, while KWS/County council rangers reported the other 57% (31/54) cases. Out of the 23 cases reported by the local community, four were passive cases (20%; 4/20 out of the total number of passive cases) and 19 were active cases (63%; 19/30, out of the total number of active cases).

Discussion

The human elephant conflict (HEC) is often defined and assessed principally on the basis of the harm inflicted on people and/or their properties. However, local communities are known to inflict retaliatory injuries on elephants, some of which cause severe wounds and even death [9]. These conflicts are numerous in areas in which people and elephants share habitat because elephants forage widely beyond the boundaries of protected areas and enter into human settlements and crop farms [2,18].

Cases of injured (physically injured or killed) elephants in the Masai Mara ecosystem are monitored by KWS veterinarians to decide whether or not intervention and/or treatment is necessary. Except for a few elephants that could not be traced in the wild due to the rugged terrain and the elephant's large ranges, most cases were treated. Almost all elephants recovered after treatment and only 2/54 (3.7%) succumbed to injuries in the period after treatment. About five cases were reported for post-mortem examination.

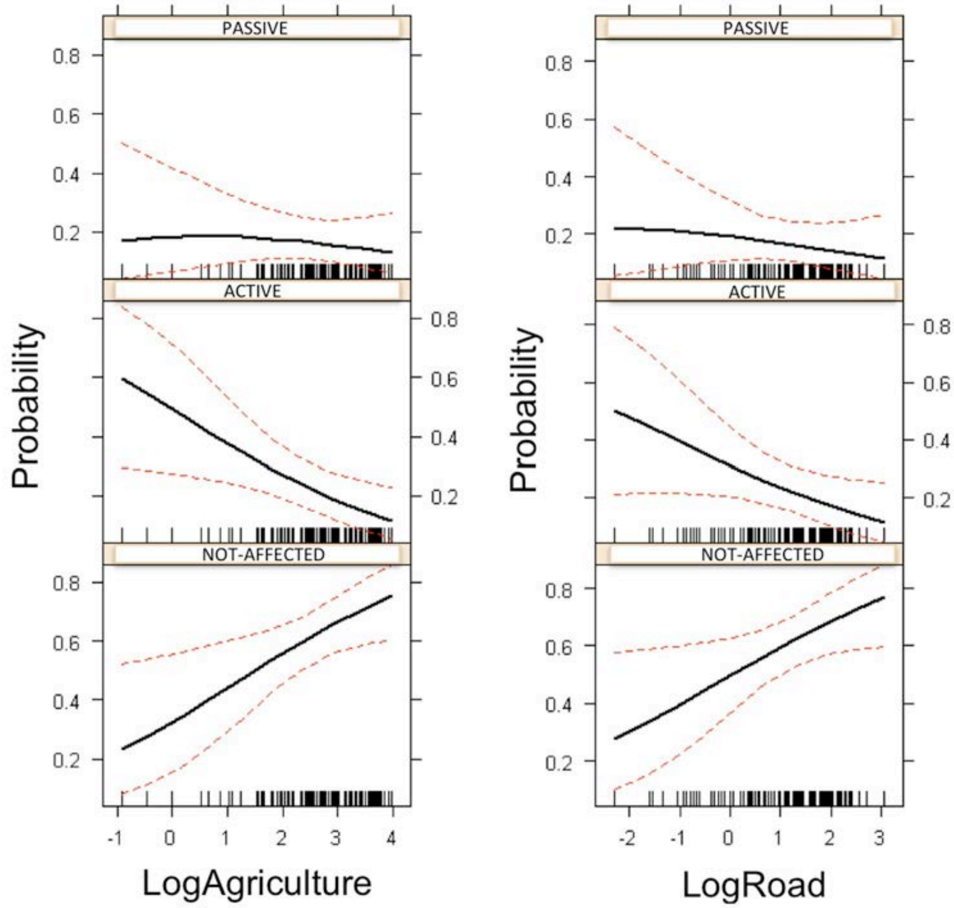

Figure 4. The effect of agricultural lands and roads on active and passive elephants injuries and unaffected elephants. This figure only includes 75 unaffected elephants, when the real number is 3,072 elephants.
doi:10.1371/journal.pone.0071179.g004

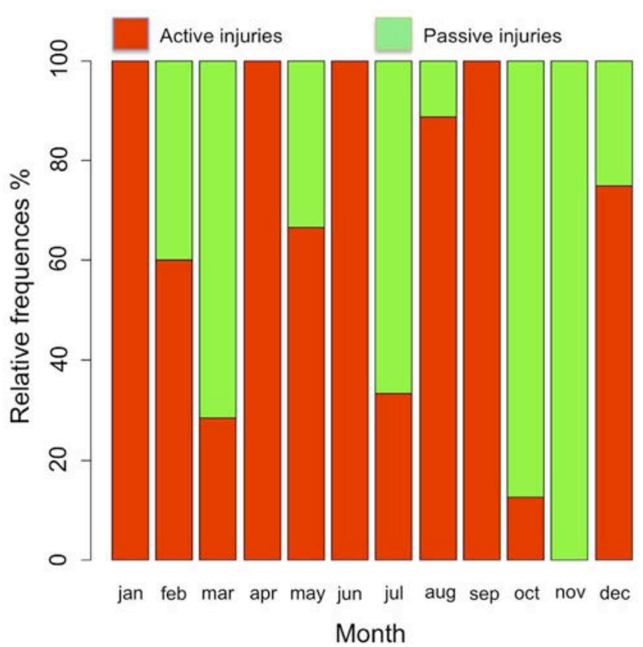

Figure 5. Monthly distribution of actively and passively injured elephant cases in Masai Mara, Kenya, between 2007 and 2011.
doi:10.1371/journal.pone.0071179.g005

HEC has been reported to occur in all areas where elephants' ranges overlap with human settlements regardless of whether or not agriculture is practiced [2,18].

Elephants are known to forage widely beyond the boundaries of protected areas and enter into cultivated crop farms. This crop-raiding behaviour is a risk factor [19] that frequently causes conflicts and results in elephant injury (physical injury or death) [9].

During the study period there were more actively caused than passively caused injuries. Passively caused injuries are not intentional and occur where local communities use snares to capture wild animals that do not target elephants specifically.

In our study males were more affected than females in cases of both active and passive injuries. Crop-raiding seems to be sex-biased towards males [20] and likely hinges on nutritional advantages that can enhance their fitness and reproductive competitiveness [21,22]. This is because sexual selection in a polygynous species such as the elephant is biased towards dominance [23]. The propensity of male elephants to raid crops makes them vulnerable to human retaliatory attacks that can cause the high prevalence of injuries observed in males [9] and in our results. Crop-raiding is rare in females – even if they inhabit areas close to crop farms [21,24] – and male elephants in Africa and Asia account for 70–100% cases of crop damage [25–27].

Our results suggest that adult elephants are more likely to be actively injured than young animals. This is probably due to the species' complex social relationships characterized by tightly led matriarchal core units offering security to young elephants that contrast with flexible male units [28]. Young male and female elephants remain in the matriarchal herd and at the hint of danger adult females (even from other social units) rush to form a tight ring around the young animals [29]. Furthermore, matriarchal groups avoid risky behaviour such as crop raiding [21] and so young elephants sustain fewer injuries. This is not the case of passive injury, which affects adults and young elephants similarly; this is logical given that passive injury is only a question of bad luck and is not specific to any age class. Wire snares, usually set at ground level along animal tracks, are indiscriminate and target multiple species of wildlife [30], and may serve both as a retaliatory weapon and for illegal capture. Farmers tend to use objects and weapons such as arrows, spears or poisoned nails that injure elephants in more subtle ways than guns, which draw too much attention [9].

Most studies report that crop destruction is the most important economic damage inflicted by elephants on humans [2,31,32]. Farming communities near national parks and forested areas in Kenya report serious crop damage caused by elephants [33]. As a result, elephants are likely to be attacked by local communities and scared away from their farming areas before they can feed on their food crops (e.g. maize, bananas, cabbages, pumpkins and carrots) or destroy mature crops and inflict serious economic losses [2,31,33,34]. Irigia [34] and Kabunge et al. [35] recorded crop losses of up to Kshs. 100,000 at Ol Ari Nyiro ranch in southern Ghana, while Barnes et al. [36] reported an average loss of 50% in some crops. Both passive and active injury cases had a significant negative correlation with crop farms (agriculture areas) indicating that elephants are more likely to be injured near crop farms than further away. The association of elephant injury and crop farms is indicative of HEC. The occurrence of injured elephants close to crop farms is suggestive of habitual crop-raiding by elephants. Our results concur with previous studies that suggest that injury cases were male dominated [9], which reflects the male bias in crop-raiding. The fact that many elephants in the Mara ecosystem concentrate near crop farms could be because crop-raiding in savannah ecosystems is triggered when the quality of wild grasses declines below the quality of crop species [37]; in forest ecosystems the availability of mature crops influences the extent of crop raiding [19]. This also explains why most of the active injuries were recorded during the dry months of the year.

Seasonal changes in the distribution of food resources have an impact on the spatial structure, demography and movement patterns of mega-herbivores such as elephants [38,39]. A seasonal variation occurred in the number of active injury cases: there was a relatively high number of cases in February and March in the dry period, just before the rainy crop-planting season begins in April– June, which is when elephants are ranging furthest in search of food and water. They are likely to pass through people's homesteads and property and so there are greater chances of conflict with villagers. The higher number of cases in August–October could be attributable to harvesting and the low rainfall season during which elephants raid farms and share watering points with livestock and people. The chances of being attacked by people and sustaining traumatic injuries are high during this period in cultivated areas within the Masai Mara ecosystem. No seasonal pattern was observed in the case of passively caused injuries indicating that local communities use wire snares with the same intensity in the dry and wet seasons.

Water is an important resource in the life of elephants and influences their spatial distribution in the landscape since they require water for drinking and mud-bathing on a daily basis [33,40]. In the present study, water sources (rivers) did not significantly affect the spatial distribution of injured elephants in the Masai Mara ecosystem but it was observed that, irrespective of injury, elephants tend to concentrate near water bodies. In habitats that are intensely poached, surface water bodies are risk areas for elephants, above all in the dry seasons [41,42].

Human population and settlements have increased in the Masai Mara ecosystem and have expanded into wildlife conservation rangelands [43]. As our results indicate, elephants concentrate close to human settlements, probably due to the inadequate buffers between elephants and these settlements.

The negative effect of roads on cases of elephant injuries can be explained by the fact that many incidences of HEC and elephant attacks occur along roads when people accidentally encounter elephants. Elephants had a greater possibility of being injured when they were near roads and so most injury cases were reported close to roads. Another factor to take into account are the extensive road networks within the reserve and the immediate surroundings due to increased human activity and the construction of roads for tourist vehicles. Generally, more elephants (injured or non-injured) were found close to roads because roads are built near elephant ranges (rather than there being any tendency for elephants to approach roads). Many roads have permeated into elephant rangelands and elephant ranges are now more accessible than before.

Our study was limited to the physical consequences of human attacks on elephants and more studies are still needed to evaluate the effect of these attacks on responses in elephant such as (i) attack/injury, (ii) behaviour (movement dynamics) and (iii) physiology (stress hormone metabolite concentrations) [44].

Local communities do not have merely negative attitudes regarding the presence of elephants and can play a pivotal role in conservation due to their direct contact with elephants and their ability to inform authorities if they observe injured animals. Curiously, local communities reported a greater proportion of active cases (63% of active cases) than passive cases (20% of passive cases). Obviously, the community members who report cases are not the culprits and so report all cases to the KWS vets without fear. Active cases, usually caused by arrows, could be more visible than passive cases, which are usually the result of placing snares. This again, highlights the importance of well-informed commu-nities in the conservation of wild animals [12].

Conclusions

The different types of human-elephant conflicts, in which elephants are attacked, injured or even killed by local communi-ties, are still neglected. Likewise, the positive role of local communities as key informants in the early detection of the injured elephants is still not fully appreciated. Our results suggest that local communities inflict active injuries on elephants in retaliation for the destruction of their properties or deaths. However, the concentration of actively injured elephants closer to crop farms and roads and away from settlements suggests that injured elephants are likely to risk repeat raids near the road network. Injured elephants are unlikely to risk remaining close to human settlements. This suggests that the presence of crop farms and roads in elephant areas is a high risk factor driving the incidence of HEC, the prevalence of injury cases and the spatial distribution of injured elephants. Local communities may also negatively affect elephants by their use of snares to capture other wild animals as bushmeat. Nevertheless, local communities do play positive roles as key informants in the early detection of injured elephants. More efforts should be made to safeguard elephants in parts of the Masai Mara ecosystem, especially in close proximity to crop farms and roads, and attempts should also be made to raise awareness in local communities and encourage them to play their parts in saving the elephants. This would reduce elephant injuries and mortalities related to the human-elephant conflict and save the cost of chemical immobilization and treatment of affected elephants.

Acknowledgments

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Author Contributions

Conceived and designed the experiments: DM VO SA MO PH RS. Performed the experiments: DM FG PO. Analyzed the data: SA RCS. Contributed reagents/materials/analysis tools: DM VO SA MO PH RS. Wrote the paper: DM VO PO SA MO PH FG.

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Chapter 3: Elephant translocations: Lessons learnt in Kenya 1995 – 2012

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Elephant translocations: Lessons learnt in Kenya 1995 – 2012

DOMNIC MIJELE[1], PATRICK OMONDI[1], VINCENT OBANDA[1], FRANCIS GAKUYA[1], SHADRACK NGENE[1], SOSPETER KIAMBI[1], RAMÓN C SORIGUER[2], SAMER ALASAAD[2,3]

[1]Kenya Wildlife Service, Veterinary Services Department, P.O. Box 40241-00100, Nairobi. Kenya. [2]Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas (CSIC), Sevilla, Spain. [3]Institute of Evolutionary Biology and Environmental Studies (IEU), University of Zürich, Zürich, Switzerland

Abstract. Human-Elephant Conflict (HEC) is one of the major challenges facing elephant management and conservation across its range. Various mitigation measures have been tried to address HEC. Elephant translocations have been tried as a HEC tool with various successes. In this paper, we review elephant translocation carried out by Kenya Wildlife Service (KWS) between 1995 and 2012 to mitigate HEC. We describe step-by-step translocation procedures that include the number of elephants moved, their sexes and age groups, reason behind translocation decision, translocation distance, and economic cost among other experienc-es. The present paper can guide the future decision-making on use of translocation in mitigating HEC in Kenya and other places

Keywords. *Loxodonta Africana*; Elephant Translocation; Kenya Wildlife Service; Human-Elephant Conflict; Kenya.

Introduction

Human-elephant conflict (HEC) refers to competition be-tween two species that often result in property loss, physical and emotional trauma and sometimes death. However, in most cases HEC is defined by crop raids, property damage, human injuries and deaths caused by elephants (Tchamba 1995; Kiiru 1995), while ignoring the retaliatory attacks that often cause debilitat-ing injuries and death on elephants (Kangwana 1995; Kioko et al. 2006; Obanda et al. 2008). In all areas that elephants and hu-mans co-exist, conflict is known to be prevalent and pervasive (Sitati et al. 2003) making it one of the most studied subjects in conservation as exhibited by numerous publications. In most of the studies on HEC, authors seem to be unanimous that compe-tition for inadequate resources and space shared between the two species underpins the conflict. In particular, land and water are the two main contentious resources. This is because of the exponential growth of human population in Africa that exerts greater demand pressure on wildlife rangelands coupled by dra-matic land use change from pastoral nomadism to sedentary ag-ricultural systems (Osborn & Parker 2002). The outcome is land fragmentation, loss of wildlife corridors and shrinkage of wild-life habitats. Land fragmentation and fencing-off private lands leads to destruction of migratory corridors, thereby permanent-ly separating populations that historically were single units. The result is creation of populations in small-disconnected protect-ed areas (PAs) marooned by human settlements. Such habitats are hotspots of HEC because they are too small to satiate the enormous foraging and nutritional needs of elephants (Smith & Kasiki 2000; O'Connell-Rodwel 2000; Sitati 2007). Several methods to mitigate HEC have been suggested and some have been applied with varying success, however, no single approach is sufficient as a universal solution for conflict alleviation (Sitati et al. 2003).

There are two main approaches to alleviating HEC: con-trolling elephant numbers and expanding elephant range (Pinter-Wollman 2012: Van Aarde & Jackson 2007). Elephant numbers may be controlled by culling, contraceptives and prob-lem animal control, while the establishment of frontier parks and wildlife corridors expands elephant ranges. Wildlife trans-location is the "deliberate and mediated movement of wild indi-viduals or populations from one part of their range to another" (Fernando et al. 2012). Elephant translocation can be used to re-duce densities in confined elephant ranges with high incidents of HEC. Similarly translocation can increase elephant numbers by re-introduction in areas with lower densities.

Methods of HEC mitigation in Kenya

Kenya is one of the few countries where elephants in their tens of thousands still roam free with an estimated elephant population of 35,000 (KWS elephant conservation strategy 2012). Kenya Wildlife Service, which is the state corporation mandated to conserve and manage wildlife in Kenya has contin-

Correspondence: Domnic Mijele (dmijele@kws.go.ke), Samer Alasaad (sameralasaad@hotmail.com)

Figure 1: Recovery, loading, transportation and release of elephants from Narok to Masai Mara National Reserve in 2012 by Kenya Wildlife Service

uosly tried various interventions to resolve HEC in the affected areas with minimum success. Some of the interventions include helicopter drives, strategic fencing, moat constructions, educa-tion and awareness, mobile problem animal control (PAC) units and strategic location of PAC outposts and resources (KWS re-ports). Historically, the management of problem elephants has evolved from brutal and inhumane methods towards careful ap-proach (Sitati et al. 2003).

The colonial government established electric fences in Tsa-vo and Aberdares NP as early as in 1950's but it failed to control HEC (Jenkins & Hamilton 1982); first, because maintenance of the fences was unsustainably too costly and secondly, neighbor-ing communities vandalized parts of the fence to give livestock access to pasture and water inside the parks. In spite of the fail-ure of fencing project, KWS established the first electric fence of 54 km in 1990 to mitigate elephant crop damage around Tsavo NP, having received the proposal from the Taita Taveta District Administration. The proponents of electric fencing suggest that it yields dual benefits of being able to reduce conflicts while at the same time boost household food production. To the conser-vation managers, electric fencing is costly because it requires perennial maintenance. Opponents of fencing claim that it can-not solve HEC because over 60% of elephants habituate outside protected areas (Waithaka 1998), which suggests that they are already within conflict zone with communities.

Moats which are deep wide trenches dug along the elephant routes have been used in the Aberdares, Meru NP, Tsavo, Laikip-ia and Maralal conservation areas of Kenya in attempt to control HEC. Elephants soon learned how to go through the moats and some moats failed because of poor maintenance. Other methods of HEC mitigation in Kenya include establishment of elephant sanctuaries and trusts, involvement of communities in wildlife conservation and inrareisolated situations, shoottokillprob-lem elephants though this approach is now unpopular. Com-pensation of human injuries and deaths caused by elephants has also been viewed as a way to encourage local communities in Kenya not to engage in retaliatory attacks that would lead to loss of more animals (Parkipuny 1996). This tool has been tried in Kenya with minimum success.

Translocation of elephants has continuosly been used to mit-igate HEC in various elephant ranges in Kenya. Elephant translo-cation strategy involves the removal of problem elephants from high conflict zones, especially farming areas, to non-farming areas or to areas with reduced elephant numbers (Sitati et al. 2003). Historically, the local community because of increased crop raids drove out elephants from Ruma NP in Lambwe valley to the Mara in 1948. The first elephant translocation exercise by KWS was in 1995, when elephants were moved from Mwea NR to Tsavo East NP, aiming to ease habitat pressure and reduce conflicts (KWS reports 1995). Subsequent elephant transloca-tions in Kenya are summarized in Table 1.

Elephant translocation process in Kenya.

Pre-translocation activities

Prior to the translocation, a series of planning and prepara-tion meetings are usually held at KWS headquarters in Nairobi and at the field station where elephant translocation is to be car-ried out. Participants at the planning and preparation meetings include veterinarians, wildlife ecologists, pilots, wardens, pro-curement officers, mechanics and GIS specialists. During such

Year	Source site	Release site	KM	Number of Males			Number of Females			Total	Purpose	Mortality	Returned elephants
				Calf	Sub- Adult	Adult	Calf	Sub-Adult	Adult				
1996	MNR	TENP	500	0	0	26	0	0	0	26	Habitat restoration	0	0
1997	LWC	KNR	400	0	0	10	0	0	0	10	HEC resolution	0	0
1999	MWC	TENP	300	0	0	30	0	0	0	30	HEC resolution	0	0
2003	OPC	MNP	250	7	9	10	9	5	16	56	HEC resolution	0	0
2005	SHE	TENP	300	24	17	20	25	12	52	150	HEC resolution	3 (2%)	2 males, 2 females, 2 calves
2006	SHE	TENP	300	9	3	9	16	5	36	78	HEC resolution	2 adult males (2.5%)	3 females
2006	NgRS	TWNP	30	6	7	9	14	9	23	68	Habitat restoration	0	2 males
2011	Narok	MMNR	150	8	9	15	3	7	20	62	HEC resolution	1 adult female (1.6%)	4 males
2012	Narok	MMNR	150	14	6	5	5	2	14	46	HEC resolution	0	0
2012	M-As	Aberdares	500	1	7	5	0	6	3	22	Habitat restoration	0	0
2012	M-As	MNP	700	1	3	2	2	2	1	11	Habitat restoration	0	2 males
		Total		70	61	141	74	48	165	559			

Table 1: Elephant translocation carried out by Kenya Wildlife Service between 1996 and 2012.

meetings, logistical arrangements of various translocation activ-ities are discussed including procurement of veterinary supplies and capture equipment, community sensitization, pre-translo-cation assessments, capture and translocation protocols and post-release monitoring.

Pre-translocation assessments of target elephant

Pre-translocation assessment of elephants is usually under-taken at the source site through aerial and ground surveys:

(i) Pre-translocation aerial survey

Pre-translocation aerial survey includes count of elephants according to the method described by Douglas-Hamilton (1997). The target area is divided into blocks of about 100km² that could be flown in a day by one team. The counting blocks are each divided into 1km grids for use as transect lines during the elephant count. Small fixed-wing aircrafts such as a four seater Cessna 182 are used during the aerial survey. The air-craft systematically search for elephants in each block flying at a height of about 100m above the ground on East to West or North to South directions along transects. Data recorded include wild-life species numbers, carcasses, livestock, human settlements, water points, market centers, schools, crop farms, other human activities and their geographical locations. Photographs are tak-en of large herds to later verify the correct count. At the end of count session the GPS flight paths and waypoints are download-ed to the computers for GIS analysis.

(ii) Pre-translocation ground survey

Intensive foot and vehicle patrols are conducted to identi-fy elephant herds, their spatial distribution and their numbers. The community is usually helpful in reporting elephant sight-ings, locations and group sizes.

Community sensitization

The communities living at the capture and the release site have to be sensitized about the translocation exercise through workshops, seminars and meetings attended by KWS personnel, area community leaders (councilors and chiefs) and area resi-dents. The meetings are held to ensure communities are made aware of the need to translocate entire or part of the population and also ensure the goodwill of the community. The facilitators explain in details the objectives of the translocation and make it clear to the communities why translocation is preferred. The process of darting elephants is dangerous to the community and they ought to be advised to stay away from the field, thickets and forests during the exercise. This is because elephants tend to scamper and may injure people on their way. Additional com-munications are made via Radios, Television, Newspapers as well as the official website page of KWS to disseminate informa-tion to the wider public on the planned elephant translocation.

Identification of capture and release site

The main factors to be considered during the identification of the elephant release sites include close proximity to water points, presence of preferred habitat, distance furthest from the settlements, and good accessibility by the heavy transportation trucks (Pinter-Wollman et al. 2009).

Translocation teams

The group undertaking the translocation should be com-posed of three teams (i) spotting (ii) darting and (iii) recovery team.

(i) Spotting team constitutes two ecologists and a pilot on fixed-wing Cessna aircraft. The spotting team sets off early in the morning to search for elephant herds intended for translo-cation within the target area. Upon sighting of suitable herds, the pilot advises the ground crew via radio communication to mobilize personnel and recovery equipment including tractors and cranes to a nearby location where the elephants darting op-eration and recovery will be undertaken.

(ii) The darting team is comprised of a veterinarian, ecol-ogist and helicopter pilot. Sometimes a cameraman may be al-lowed on board depending on the capacity of the helicopter. The scientist selects the target herd as well as the specific individual to be darted for translocation. The pilot coordinates with the veterinarian and positions the helicopter in a suitable angle to ease darting by the veterinarian.

(iii) The recovery team comprises of veterinarians, capture rangers (assist in physical restraint and positioning of recum-bent animals as well as loading), scientists, drivers, and security rangers. Veterinarians assess the general health status of the animal, monitor physiological parameters, administer any oth-er drug as situation may require on immobilized elephants and eventual administration of revival drug once in the transport truck. Veterinarians are also in charge of the collection of biolog-ical samples such as blood, tissue and faecal material. Ecologists take other metadata such as georeferences, body morphomet-rics that include the tail length, shoulder heights, head to tail length, ear circumference as well as fitting GSM-GPS collars.

The capture rangers are responsible for loading the animals onto recovery tracks and loading them onto the transportation trucks. The armed wildlife security rangers remain vigilant and warn of approaching animals and/or scare them off to ensure all personnel are safe.

Sighting, darting and monitoring of immobilized elephant

The aerial spotting team is supposed to locate target herds of elephants and inform the recovery team to move the translo-cation equipment closer to where darting and recovery will take place. The spotting team then continues to monitor the herds as the equipment is being moved in place. Once all the equipment is in place and recovery team ready on the ground, the spotting team then calls the darting team to the location of sighted herds and ensure that the darting team has visual of the herds. The darting team then selects a herd to concentrate on. In case the selected herd is larger than 10 elephants, the darting team splits it into small manageable family or bachelor units of about 5 or 6 individuals.

The darting is usually done in a logical sequence starting with the oldest (matriarch) to the youngest calf. The age-related sequence of capturing aims to avoid young elephants being im-mobilized first and injured by older ones as they fall down or try to wake younger elephants up. Cow-calf groups including sub-adults are preferably darted and transported together in the same container. Adult bulls are usually darted and transported singly to avoid fighting and injuring each other while on tran-sit. The helicopter herds the elephants to suitable open grounds with favorable terrain close to the ground team for darting.

Once an elephant is darted, the recovery team is called in but spotting team and sometimes the darting team from the he-licopter monitors the animal until it falls down. The recovery teams are directed to the fallen animal by the light aircraft or sometimes the helicopter. This team then starts monitoring the animal and later after collecting samples and doing the measurements, the animal is loaded to a recovery truck using a crane. The elephant is then transported and loaded to a trans-portation truck. This process is repeated until a good number of elephants (4 for bulls, and 10 for family herds) are successfully captured and loaded onto a transportation container.

Darting is usually done from the helicopter. Elephants are darted with 9.8 mg/ml Etorphine Hydrochloride (M99® Norva-tis South Africa (Pty Ltd/ (Edms) Bpk) combined with hyaluro-nidase to fasten the absorption and reduce the induction time. The dosage depends on the age of the elephant to be immobi-lized.

Three-milliliter Dan Inject® darts (Norvatis South Africa (Pty Ltd/[Edms] Bpk) containing the appropriate dose of the drug with 2.2×60mm collared or plain needles are delivered through a Dan Inject® dart-gun into the rump or thigh muscle of the elephants. The darting is usually done from a helicopter hov-ering above the elephants at a close range of about 10–15me-ters; the dart is aimed at 45° downwards to the elephant.

After darting, the veterinary doctors observed the darted el-ephants for signs of narcosis. On average, induction time (time from dart impact to recumbency) should be about 8 minutes. If no signs of narcosis are visible after 15 minutes the animal is re-darted.

A maximum of six elephants are usually darted at a time to allow for efficient monitoring, recovery and loading. Once the elephant fall and after ensuring adequate security in the area, the ground team consisting of veterinarians, animal/laboratory technicians, capture rangers and scientists is called in by radio communication from the helicopter to attend to the immobi-lized elephants.

On reaching the immobilized animal, the veterinarian exam-ines the elephant to ensure it is in a stable state of anesthesia and patent airways by straightening the trunk and removing ob-structing objects. The immobilized elephant is then positioned on lateral recumbency to minimize pressure of the huge abdom-inal contents on the lungs.

Vital parameters including temperature, pulse rate and respiration rate are closely monitored and determined at 5 minute intervals then recorded using standard immobilization forms. Pulse rate is measured by palpating the middle ear artery, respiration rate by counting the frequency of air movements in the trunk and rectal temperature recorded (Gakuya et al. 2003). In addition oral mucosa is examined to monitor the level of tissue oxygenation.

Dart wounds are treated with antimicrobial ointment. Sim-ilarly the eyes are infused with antimicrobial ointment (Op-ticlox®, Norbrook laboratories) to prevent desiccation of the cornea and covered by turning the earflap over it. Overheated animals are doused with copious amounts of water particularly on the ears to keep them cool.

Immobilized elephants are usually examined for external injuries including wounds and foreign objects such as arrowheads as well as abscesses, which are then treated appropriately. A long acting antibiotic (Amoxicillin trihydrate 150mg/ml or oxy-tetracycline Hydrochloride 200mg/ml) is administered intra-muscularly to the neck muscles in all immobilized elephants for prophylaxis against opportunistic infections following the stress of capture and transportation. Dexamethasone sodium 1% is administered to animals with septic wounds and those that ran too much before capture. Animals that manifested compromised respiration are given 400mg of doxapram intravenously.

Collection of biological samples

Forty milliliters of blood are drawn from the superficial ear veins in sterile syringes and dispensed into plain and ED-TA-coated tubes. EDTA blood samples are used for hematologi-cal analysis and the rest preserved in liquid nitrogen for genetic studies. Serum is harvested from the plain tube blood samples by centrifugation after 6 hours of standing to allow for clot formation. The serum is aliquotated and preserved in liquid nitrogen for various serological tests.

In addition, tusk scrapings and hair roots are also taken and preserved for various studies. Fecal samples are collected from the rectum for parasitological analysis. Tick samples are also collected from various body parts for identification and docu-mentation.

Morphometric measurements

Various body measurements are usually taken to aid in elephant identification and post release monitoring. These include trunk length, back length, tail length, shoulder height, spoor diameter, ear diameter, tusk circumference and lip circumference. Notable features are documented such as notches, holes and slits on the ear and missing or broken tusks. Photographs of ear venation and tusk appearance are also taken to assist in indi-vidual identification during the post-release monitoring. Plastic zip tags are fitted on the tails of immobilized elephants and in addition elephants are numbered using waterproof paints to aid in post release monitoring.

Recovery, loading and transportation

Immobilized elephants are then loaded into recovery trucks and tractors using cranes and transported to the loading site. They are then transferred to a conveyor belt from where they are loaded onto a transportation truck. Elephants are main-tained in narcotized state during recovery and transportation to the loading site by administering etorphine Hcl (M99®Nor-vatis South Africa (Pty Ltd/(Edms) Bpk) intravenously into su-perficial ear veins when they showed signs of recovery. Signs of recovery include increased rate and depth of respiration, in-creased frequency of movement of the trunk and the ears as well as paddling of the legs. Maintenance dose is usually calculated as a quarter of the initial darting dose depending on the age group. At the loading site, conveyor belts are used to move the immobilized elephants into a recovery container. Here the ele-phant are quickly revived from neurolepto-analgesia by intra-venous administration of diprenorphine Hcl (M50-50®Norvatis South Africa (Pty Ltd/(Edms) Bpk) at a rate of three times the initial dose of etorphine administered. In addition, a tranquil-lizer, azaperone-tartrate of (60-120mg depending on the size and age of the animal) is administered intramuscularly to keep the elephants calm during transportation. After revival, the ele-phant is closely monitored from outside the recovery container until it is fully revived before being prodded to move into the transportation truck, which by that time is already attached to the recovery container.

Release of elephants

At the release site, the transportation truck is reversed into an offloading ramp and the elephants allowed to voluntarily walkout of the transportation crate into the wild (Figure 1).

Estimate costs of elephant translocation in Kenya

The actual cost of elephant translocation is usually obtained from the cost of transportation, immobilization drugs and dart-ing equipment, helicopter cost and personnel costs. However, the number of elephants to be moved and the distance from the source to release site are the major factors to be considered when estimating the cost of elephant translocation. Many ele-phants will require more immobilization drugs, more darting equipment, more helicopter hours and more days. This would result into increased costs of these items, making the exercise quite expensive. If the operation lasts many days, this will in-crease the accommodation and personnel costs. Translocation of many elephants over long distances translates to a higher cost of translocation as compared to few elephants moved over a short distance.

Personnel cost

On average 5 elephants are translocated per day in the previous translocation exercises in Kenya. About 60 personnel including veterinarians, biologists, laboratory technologists, pi-lots, drivers, mechanics, security officers and GIS analysts are required for a translocation exercise targeting to move more than 10 elephants. The average cost of personnel is 50 USD/per-son/day, therefore 60 personnel will require 3,000 USD/day to move an average of 5 elephants/day.

Immobilization & Darting equipment

Each etorphine Hcl/diprenorphine Hcl (M50-50®) pack which costs about 450 USD can be used to immobilize at least 3–5 elephants depending on age and sex. Each elephant is esti-mated to cost about 200 USD for drugs and darting equipment.

Transportation cost

Transport cost, for the transportation truck, escorting vehi-cle and maintenance costs, is estimated at 5 USD/Km. Five ele-phants can be moved per trip.

Impact of translocation on HEC in Kenya

There was significant decline in Kenya as a result of ele-phant translocation. For instance, there has been a significant annual decline in HEC in Narok during the two-year period (2011–2012) after translocation, ($p<0.05$). A total of 518 HEC cases were reported in the year 2010 while only 236 conflict cases in the year 2012. The decline is attributed to transloca-tion of the 106 elephants from Narok to Masai Mara National Reserve. In Mwea National reserve HEC declined to nil after a successful elephant translocation to Tsavo East National park. A well-maintained electric fencing controlled the few remaining elephants.

Discussions

Translocation is often used to reduce human-elephant con-flict (Muir 2000; Wambwa et al. 2001; Dublin & Niskanen 2003). However, it has notable risks, which require attention before im-plementing the process. The common risks include (i) elephant mortality during the translocation process (Pinter-Wollman et al. 2009), (ii) elephants can sometimes reject a release site and return to the source site referred to as homing (Fernando et al. 2012), (iii) increase elephant injury/death caused by human at-tacks (Fernando et al. 2012), and (iv) translocation process can be quite expensive and requires cost-benefit analysis prior to conducting elephant translocation (Grobler et al. 2007).

In South Africa the known mortality rate of all elephants translocated since 1994 is only 2.7% (27 known mortalities out of 1,014 elephants). The cause for these deaths vary from the transport truck overturning, elephants with predisposed dis-ease problems, elephants falling accidentally in water or down a cliff after being darted, and failure of equipment (Grobler et al. 2009). In Kenya, all the elephant translocation operations have recorded quite low mortality rates of below 5% in most instances (Table 1). For example in the first phase of elephant translocation from Narok to Masai Mara in 2011 only one sub-adult female elephant died out of 62 elephants (1.6%). This par-ticular elephant was confirmed to have died of a capture related complication referred to as 'pink foam syndrome' (Gakuya et al. 2003). Pink foam syndrome is usually characterized by severe respiratory distress, edema of the lungs and discharge of blood tinged fluid from the trunk following capture. The complication began soon after the elephant had been recovered and was be-ing transported to the loading site. The elephant had fallen in a difficult terrain, which was very rough and difficult to access by recovery trucks. This led to delay in the recovery process and complicated loading which had effect on elephant physiological process hence 'pink foam syndrome'.

However, no elephant mortality occurred in the second phase of Narok translocation. Previous elephant translocations in Kenya also recorded very low mortality rates, for instance, the Shimba hills-Tsavo translocation lost three elephants. The caus-es of these mortalities were sometimes speculatively attributed to rough terrain, equipment failure and long distances of trav-elling before release. We analyzed the available data in KWS on elephant translocation between 1995 and 2012. Our analysis re-vealed that chances of elephant mortalities increase as the num-ber of translocated elephants increase (Figure 2). Hence need to break-up major translocations into phases targeting about 50 elephants each rather than moving large numbers of elephants in a single major operation. Our data have shown that there is no relation between the translocation distance (Km) and elephant mortality (%), (Figure 3). Elephants seem to be quite resilient and can withstand transportation over long distances of up to 700km and taking even more than 12 hours on transit.

Elephants can sometimes reject a release site and return to the source site, the behavior has been noted in a number of trans-location operations. Eight of the 109 translocated elephants left the release site in Tsavo National Parks, and either returned to Shimba Hills (n = 6) or ended up elsewhere on the coast, near Malindi (n = 2) (Pinter-Wollman et al. 2009). A larger propor-tion of males left the release site than females with calves. Four of the 15 adult males whose fate is known (26%) left the release site, and two of the 39 translocated female–calf units whose fate is known (5%) left the release site (Pinter-Wollman et al. 2009).

In Narok, 4 males returned to the source site barely 2 weeks after translocation covering a distance of about 100kms. Chanc-es of elephants returning to source site after translocation de-creased with increase in distance (Figure 4). Males would be more likely than females to leave the release site. Males are the dispersing sex and travel long distances in search for mates, while females and their offspring live in matriarchal groups (Moss & Poole 1983). Therefore, males would be more likely to leave the release site, or explore it more extensively if they re-

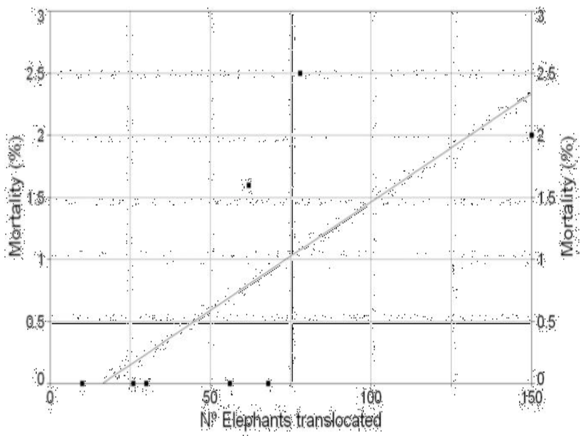

Figure 2: Relationship between the number of the translocated elephants and the mortality (%), (R2 =0.284). KWS 1995-2012.

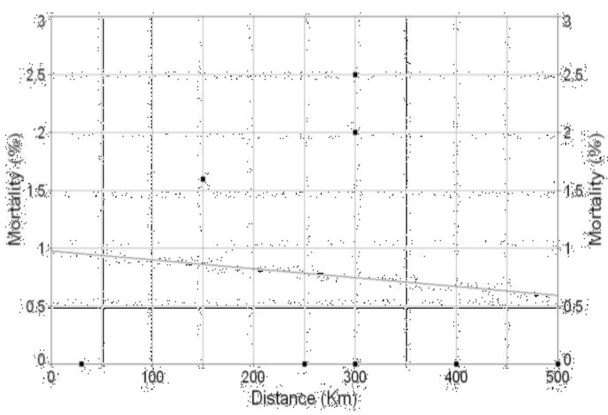

Figure 3: Relation between the translocation distance (Km) and the mortali-ty (%), (R2 =0.01). KWS 1995-2012.

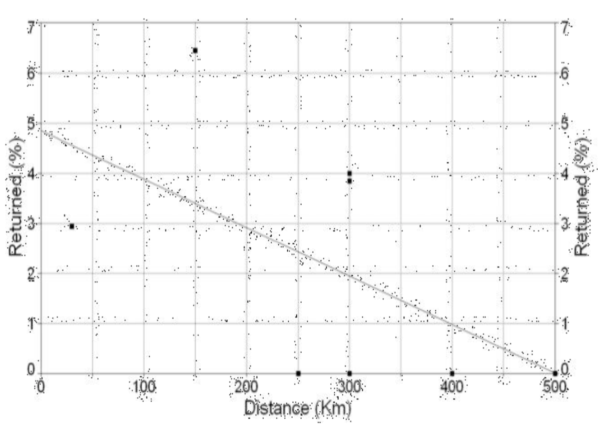

Figure 4: The relation between the translocation distance (Km) and the possibility (%) that the elephants return to the source site, (R2 =0.307). KWS 1995-2012.

main, than females whose movements may be confined by the physical abilities of young calves.

The size of the elephant translocation equipment, because it can restrict access to locations, is an important limiting factor associated with elephant translocation. Heavy equipment may have limited access on poorly managed roads (Grobler et al. 2009). However, access limitations can often be circumvented by experienced helicopter pilots, who are able to herd elephants over long distances (up to 20 km) to more accessible locations (Grobler et al. 2009).

Financial cost is a major limitation for elephant transloca-tion. All the age groups or sizes of elephants can easily be trans-located by the recent translocation techniques available. Recent techniques, modern equipment and experienced personnel have made it possible to perform any translocation required or desired. The task of moving a large number of elephants, as many as possible is purely dependent upon human effort and financial resources (Grobler et al. 2009).

The cost of a translocation operation depends on several factors. The factors that contribute the greatest cost and great-est variability in cost to translocation deal with: distances that equipments (including the helicopter) have to be moved to get to the capture site and the distance the elephants are moved. Additionally, the travel and accommodation costs of personnel may be high, depending on the location and duration of the operation. In terms of the treatment of elephants, full-grown adults are more expensive to dart than smaller individuals be-cause adults require a larger dosage of drugs for sedation (Du Toit 2001). The geographic location of target elephants has no effect on the cost of darting (Grobler et al. 2009).

Transport costs and personnel costs remains constant irre-spective of how many elephants are translocated per day. How-ever, there is reduction in cost per elephant for translocating an increased number of elephants. Due to high fixed daily expens-es, the cost per elephant for moving fewer than 10 individuals is much higher than for moving a higher number of individuals (Grobler et al. 2009).

Conclusions

Human Wildlife Conflict (HWC) is a fairly old problem and occurs wherever the range of wildlife and humans overlap. Re-ports from Kenya indicate that majority of the reported HWC in the last decade are related to HEC incidents. One of the most effective tools to mitigate HEC is elephant translocation. In this review we summarized step-by-step elephant transloca-tion procedure as it is carried out by KWS. Between 1995 and 2012, KWS translocated 559 elephants, the average transloca-tion distance was 325 km, and the average mortality was 2.3%. The present paper can guide the future decision-making in the use of translocation as a mitigation option for HEC in Kenya and elsewhere.

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Competing interest

The authors declare that they have no competing interest

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Chapter 4: Influence of massive and long distance migration on parasite epidemiology: Lessons from the great wildebeest migration

Domnic Mijele[1]*, Takashi Iwaki[2], Patrick I. Chiyo[1], Moses Otiende[1], Vincent Obanda[1], Luca Rossi[3], Ramon Soriguer[3], Samer Alasaad-Angelone [4, 5]*

[1]Forensic and Genetics Laboratory, Kenya Wildlife Service, P.O Box 40241–00100, Nairobi, Kenya.

[2] Meguro Parasitological Museum, 153-0064, 4-1-1 Shimomeguro, Meguro-ku, Tokyo, Japan.

[3]Dipartimento di Produzioni Animali, Epidemiologia ed Ecologia, Università degli Studi di Torino, Via Leonardo da Vinci 44, I-10095 Grugliasco, Italy.

[4]Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas (CSIC), Avda. Américo Vespucio s/n 41092, Sevilla, Spain.

[5]Institute of Evolutionary Biology and Environmental Studies (IEU), University of Zürich, Winterthurerstrasse 190, 8057 Zürich, Switzerland.

D Mijele: dmijele@kws.go.ke; T Iwaki:iwaki@kiseichu.org; PI Chiyo: pchiyo@gmail.com; M Otiende: motiende@kws.go.ke; V Obanda: vobanda@kws.go.ke; L Rossi: luca.rossi@unito.it; RC Soriguer: soriguer@ebd.csic.es; S Alasaad-Angelone: sameralasaad@hotmail.com

Abstract

Very little is known about the influence of massive and long distance migration on parasite epidemiology. Migration can simultaneously minimize exposure to common parasites in their habitats and increase exposure to novel pathogens from new environments and habitats encountered during migration, while physiological stress during long distance movement can lead to immune suppression, which makes migrants vulnerable to parasites (López et al. 2013). In this paper we investigated the diversity, prevalence, parasite load, co-infection patterns and predilection sites of adult gastrointestinal helminths in 130 migrating wildebeests and tested for their relation with animal age, sex and migration time, and compared them with the non-migratory wildebeest.

Surprisingly only four parasite species were found: *Oesophagostomum columbianum*, *Haemonchus placei, Calicophoron raja* and *Moniezia expansa*, which was lower number than found in non-migratory wildebeest, suggesting a beneficial role of long distance migration. The recovered parasites were generalist parasites known to infect livestock, which suggests that wildebeest and livestock (dominating landscapes during migration) are at potential cross-infection risk. Specific parasites occupied distinct sections of the gastro-intestinal tract of the animals, and parasite co-infection was as randomly expected. In general, there was a negative relation between parasites diversity and prevalence from one side, and host age from the other side; the older the animal the less parasite diversity and load it has, which suggest that wildebeest acquire protective immunity against these parasites with the age. Parasite load was higher among wildebeest crossing the Mara Bridge (early migrants) comparing with those crossing the Serena Bridge (late migrants), which suggests that early migrants may suffer heavy parasitism as a result of nutritional stress in their areas of origin. Animal sex, unexpectedly, had no significant effect on parasites diversity and load.

In summary, there is a potentially limited nutritional stress during massive and long distance migration which could lead to immune suppression on the early migrant wildebeest, while generally speaking there is a positive effect of the migration by minimizing exposure to common parasites. The potential parasitic cross-infection between wildebeest and livestock is a real risk to be taken into account in the management of wildebeest corridors, with special focus on the vulnerable young migrators.

Keywords: Gastrointestinal helminthes; Serengeti-Mara ecosystem; *Oesophagostomum columbianum*; *Haemonchus placei*; *Calicophoron raja*; *Moniezia expansa*; co-infection; parasite competition; parasite facilitation; parasite predilection sites; parasite load; cross-infection

Introduction

Long distance migration, common in several species of birds, butterflies and mammals can affect the diversity, prevalence, and burden of parasites and pathogens in migratory populations of these species. Parasites epidemiology of migrant animals are of pivotal interest, nonetheless very little is known regarding parasite prevalence and diversity in migratory populations of many mammalian species including the blue wildebeest (*Connochaetes taurinus*).

Over a million blue wildebeests are known to migrate annually from the Serengeti in Tanzania to Masai Mara in Kenya covering approximately 3,000km in search of adequate pasture and water. During the migration period, wildebeests come into contact with various parasites or pathogens, characteristic of the different geographical areas and habitats in their migration routes (Alerstam et al., 2003). They also come into contact with many livestock and other resident wildlife.

Long distance migration has a great influence on wildebeest mortality, because it is energetically costly, many animals die from physical exhaustion, drown as they cross the Mara River and are attacked by predatory crocodiles. Migration is also physiologically stressful, and migration-induced stress may cause immune suppression thereby increasing infection risk with different parasites and pathogens. Such physical exhaustion, immune suppression and death can be exacerbated in individuals who already have heavy parasite burdens. Gastrointestinal parasites in blue wildebeests can cause loss of appetite, poor feed conversion efficiency, potentiation of other pathogens or even death (Ezenwa, 2003, Penzhorn, 2000). In natural populations, a diverse array of macro parasites, micro parasites, and mutualists form a complex community within each individual host (Thrall et al., 2007). Thus, the seasonal movements adopted by many animal hosts are likely to affect parasites and pathogen prevalence (Alerstam et al., 2003, Gylfe et al., 2000).

However, long distance migration may enhance avoidance of parasite, even the selection of parasite free habitats, as suggested in shorebirds (Piersma, 1997) and reindeers (Folstad et al., 1991). The parasite fauna of non-migratory wildebeest is well documented (Horak et al., 1983) but nothing is known about the parasites of migratory wildebeest.

Parasite interactions and co-infections may also affect the host's immune response leading to immune suppression or cross-reactive immune responses (Cobey and Lipsitch, 2013, Pedersen and Fenton, 2007). Currently, insights into host–parasite interactions are still largely based on studies involving single parasite species infecting single hosts. Yet, in the real world, hosts are often infected by numerous parasite genotypes of the same or different species simultaneously (Ulrich and Schmid-

Hempel, 2012). Given the incredible prevalence and diversity of parasites within host populations, it is not surprising that host individuals are often found to be co-infected with multiple parasite species (Petney and Andrews, 1998). However, research into host-parasite interactions remains dominated by the study of single infections in isolation, with only occasional consideration for the mechanistic interactions between parasites and their ecological and evolutionary implications (Lockhart et al., 1996, Pedersen and Fenton, 2007, Fenton et al., 2010, Lello et al., 2008). Since migratory wildebeests are likely to harbor multiple helminth infections and fresh carcasses were available from annual natural deaths, they provided an opportunity to investigate the epidemiology of the most common gastrointestinal parasites and parasite predilection and co-infection patterns within hosts. These patterns may help reveal parasite interactions like competition for host resources or attachment sites within the host (Cattadori et al., 2007, Mideo, 2009) or interactions between parasites and the host's immune system. The literature that deals directly with the distribution of helminths in the gastrointestinal tract of vertebrates is relatively limited (Crompton, 1973). Studies on parasite co-infection have mainly focused on exposure risk factors and little attention has been given to patterns of parasite predilection sites within hosts and its relationships with patterns of co-infection since this may reveal aspects of parasite ecology such as competition for attachment sites or resources within host species (Cattadori et al., 2007, Mideo, 2009). Interactions between parasites may be indirectly manifested via the host's immune suppression by one parasite benefiting another (Fenton and Perkins, 2010, Graham, 2008, Hawley and Altizer, 2011, Telfer et al., 2010).

This study aims to; 1) evaluate the diversity, prevalence and parasite load of adult helminths in migratory wildebeests and compare them with the non-migrant wildebeest, 2) test the influence of host age, sex and migration time on parasite diversity and load, 3) determine the co-infection patterns, and 4) the predilection sites of helminths in the gastrointestinal tract of the wildebeests.

Material and Methods

Study area

The study was conducted in the Masai Mara National Reserve (MMNR) located in southwest Kenya along the Kenya-Tanzania border (1°10'000 and 2°10'000 S, 34°14'500 and 36°10'000 E) (Ogutu et al., 2011). MMNR occupies an area of approximately 1510 square Kilometers and has a high density of wildlife populations including large mammals such as African elephants, lions, leopards, African buffaloes, black rhinoceros, wildebeests and several antelope species (Mijele et al., 2013). The reserve is contiguous with the Serengeti National Park on the Tanzanian side and is traversed by the Mara River flowing from the Mau escarpments across the reserve into Serengeti and drains in Lake Victoria. The

MMNR and Serengeti form part of the blue wildebeests' migration route. We selected two different crossing areas: Mara Bridge (where the early migrant wildebeest cross the river), and Serena Bridge (where the late migrants cross the river).

Post mortem procedures and parasite sampling

Post-mortem examination was carried out on 130 migratory wildebeests that drowned along the Mara River between 2010 and 2012 at three different locations along the Mara River (Figure 1). Records of sex, age and presence or absence of gastrointestinal parasites from all wildebeests that were dissected were taken. This sample had 66 adults, 13 sub-adults, and 51 juveniles comprising 65 females and 65 males. Wildebeest carcasses were retrieved from the river using an anchor attached to a rope. Each carcass was put on dorsal recumbence and cut open on the ventral part of the abdomen along the linear alba to access the abdominal contents.

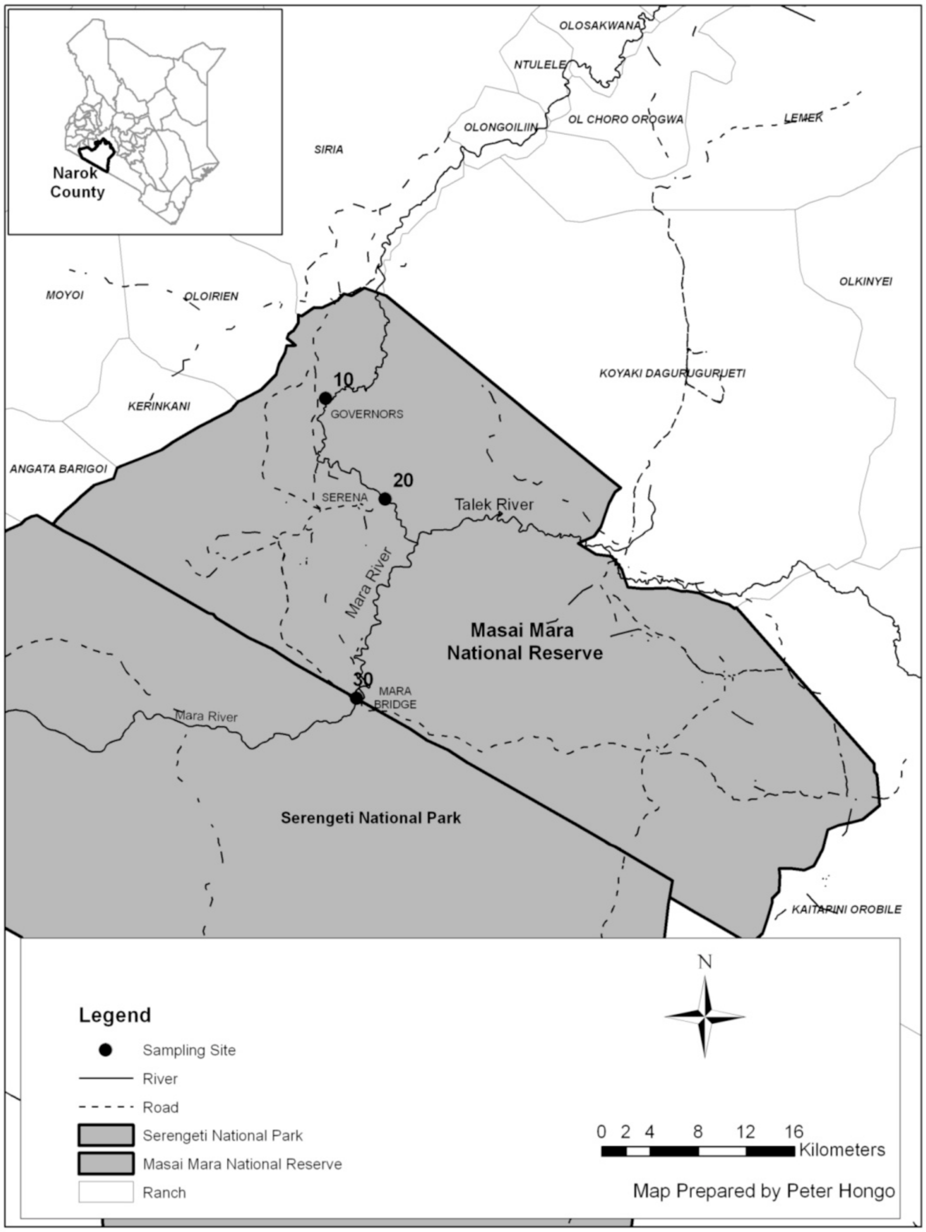

Figure 1. Map of Masai Mara National Reserve and associated protected areas.

Once the abdomen was opened, prestomachs, abomasum, small and large intestines were ligated at omaso-abomasal, abomaso-duodenal and ileo-caecal junctions to prevent parasites spilling from one part to another. The ligated gastrointestinal tracts were processed for helminth recovery as described by Horak, Meltzer and De Vos (1982). Specifically, contents from each section of the gastro-intestinal tract were washed through a sieve 0.5 mm. All material that was not washed was first examined by eye and all visible adult worms were isolated and counted. Secondly, we examined all the contents using a hand held 10X magnifying glass and all tiny worms were picked and isolated from each section of the gastrointestinal tract. Worms were first classified based on gross morphology and then counted. Several worm samples were collected into tubes according to the site in the gastrointestinal tracts it was collected from and according to our field ID. Worm samples were preserved in 70% ethanol in the field and a representative sample of this field collection based on our field IDs and predilection sites were sent for identification at Meguro Parasitological Museum, Japan.

Age estimation of Wildebeest carcasses

The age at death of wildebeest was estimated based on horn length and shape, body size and pelage colour and tooth wear. Detailed relationships between horn length and shape and wildebeest age are described in (Talbot and Talbot, 1963) and a detailed description of assigning age based on tooth wear patterns are available in (Attwell, 1980). Juveniles were classified as animals one year or less, sub adults were classified as animals between one year and 2.5 years of age. Animals above 2.5 years were classified as adults.

Morphological identification of parasites and species diversity

In the lab, the parasite samples were washed in water overnight in order to remove the fixative, relax internal organs and enhance clear examination of internal organs on a microscope. The cestodes and trematodes were then placed between two glass slides tightened by cotton thread and left to flatten in 50% acetic acid for one week, to about 1 mm thick. The cestodes were stained by alum carmine, dehydrated in ethanol, cleared by xylene and mounted by Canada balsam. The trematodes were unstained and cleared by glycerine. The nematodes were directly cleared by glycerine. All specimens were observed and identified at 50-400 magnification under a light microscope.

Statistical analysis

Animal sex, age and migration time on the prevalence and infection load of adult gastro-intestinal parasites

We used a generalized linear model with a Poisson family and an identity link function to test the hypothesis that age, sex and migration time (represented by location of entry into the Mara National Reserve) are important predictors of gastrointestinal helminthes prevalence and load in wildebeests. In the case of parasite prevalence and because we had ordered information in the data (4 parasite species) we also tested a proportional odds ordinal logistic regression models instead of a multinomial model (unordered). For both the GLM (Generalized Linear Model) and the proportional odds ordinal logistic regression models, we used number of parasite species by wildebeest as a dependent variable.

Parasite predilection sites of adult gastrointestinal helminths

We examined the presence and co-infection possibility of common helminthes parasite species in the various parts of the gastrointestinal tract. For testing this association, we used a $\chi 2$ test.

All statistical analyses were performed using R software version 3.2.0 (R Development Core Team 2015).

Results

Parasite identification and species diversity

Four species (a cestode, a trematode and two nematodes) were identified in the studied wildebeests.

The single cestode belonged to genus *Moniezia* of the family Anoplocephalidae (Beveridge, 1994). From the arrangement of interproglottidal glands (Schmidt, 1986, Spasskii, 1951, Yamaguti, 1959) , this cestode was classified as *Moniezia expansa* (Figure 2a & 2b).

The trematode belonged to the genus *Calicophoron* of the family Paramphistomidae (Jones, 2005). We observed small tegumental papillae arranged densely around the genital atrium, that is typical of *Calicophoron raja* (Eduardo, 1983). The body length was approximately 7 mm and eggs size was 145-150µm, consistently with the description of this species (Figure 2 C, D & E).

One of the nematodes was found to belong to the genus *Oesophagostomum* of the family Chabertiidae (Lichtenfels, 1980) using the structure of head and uterus. According to key to the species (Popova, 1958), this nematode was identified as *O. columbianum* (Figure 2 F, G & H). Body length of this sample was 12.3-13.9 mm in males and 16.8-20.1 mm in females. The number of outer/inner crowns in head was about 20/40. Spicule length was 752-886 µm. Distance from vulva to tail end was 1.22-1.39 mm. The whole body size, lengths of spicules and position of vulva are coincident with the description of this species.

The other nematode belonged to the genus *Haemonchus* of the family Trichostrongylidae (Durette-Desset, 1983) based on the structure of *bursa* and spicules of male. The morphological measurements of our samples were consistent with the description for *H. placei.* Body length was 13.1-13.7 mm in the males and 22.5-22.8 mm in females. The right and left spicule length was 465-467 µm, and 466-473 µm respectively (Figure 2, I & J). Gubernaculum length was 224-232 µm and the distance from vulva to tail end in a female was 4.12-4.28mm. The position and size of barbs of spicules in our sample of *Haemonchus* was a little different from the descriptions for *Haemonchus placei* and *Haemonchus contortus*; spicule barb length in our male sample was 77-87 µm, and 34-43 µm for the right and left spicule barbs respectively. According to the species keys in Skrjabin et al. (Skrjabin et al., 1954), this nematode was classified as *Haemonchus contortus*. However, according to the Lichtenfels et al. (Lichtenfels et al., 1994), who studied the morphology of *H. contortus* and related species, the

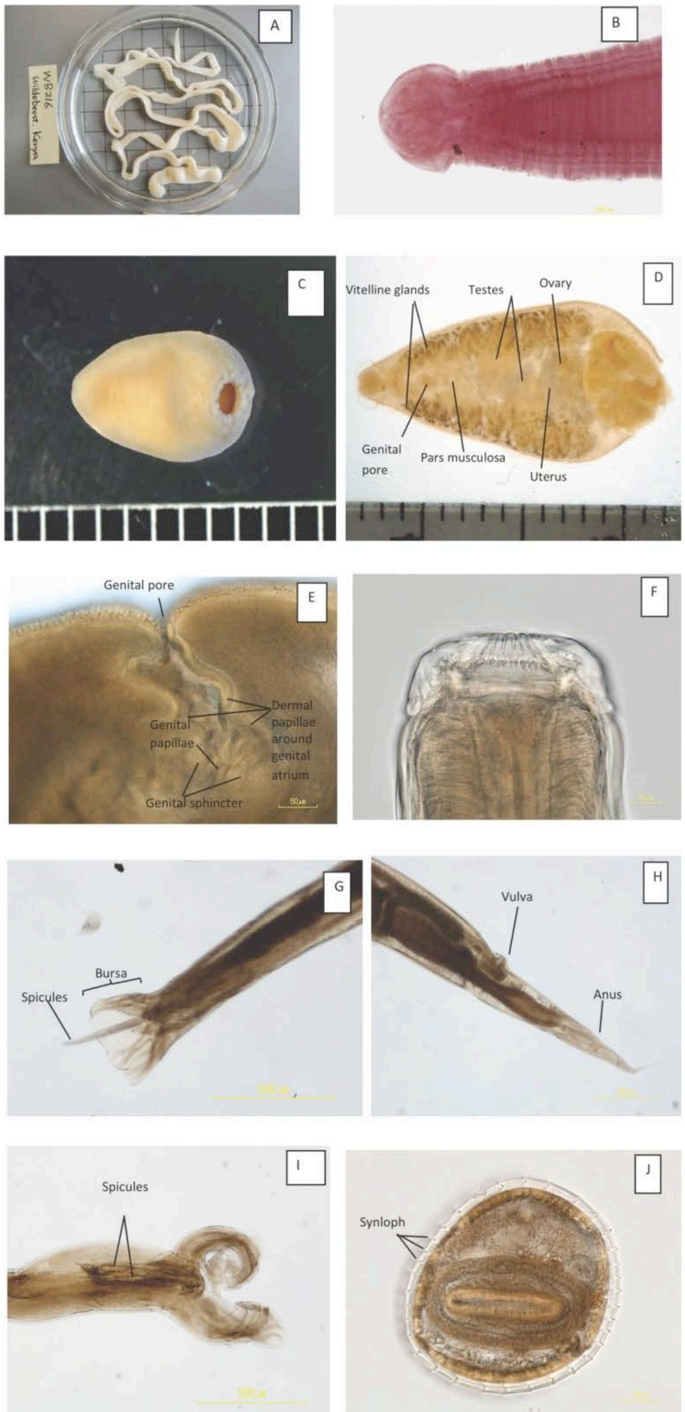

Figure 2. Images showing identification features of the four gastrointestinal parasites of wildebeest. A is a whole worm of *M. expansa*, B is a scolex of *M. expansa* after pressing and staining, C is a whole body of *C. raja*, D is the whole *C. raja* worm flattened and cleared, E is the genital atrium of *C. raja* hand sectioned and cleared, F is the head end of *O. columbianum* with corona radiate, G is the tail of a male *O. columbianum* showing bursa and spicules, H shows the tail of female *O. columbianum* with vulva, I shows the tail of a male *H. placei*, and J shows a cross section of a female *H. placei* at about ¼ of body length from head end.

Present nematode sample is thought to be *Haemonchus placei* because of the number of synlophe (*H. contortus* ≤30/*H. placei* ≤34) (Figure 2, I & J). The published length for *H. contortus* is 37-48 µm, 19-24 µm for right and left barbs (Lichtenfels et al., 1994) respectively whereas that for *H. placei* is 45-60 µm, 22-23 µm for right and left barbs spicules respectively.

Parasite predilection sites of adult gastrointestinal helminths

Chi-square tests analyses revealed significant associations between parasite presence and distinct sections of the gastrointestinal tract (Figure 3). *M. expansa* was significantly more present in the small intestines ($\chi2 = 90.93$, df = 5, $P \leq 0.001$), while *O. columbianum* was significantly more in the large intestines ($\chi2 = 275.58$, df = 5, $P \leq 0.001$). *H. placei* was more frequently found in the abomasum than in any other part of the gastro-intestinal tract ($\chi2 = 95.31$, df = 5, $P \leq 0.001$). *C. raja* which was predominantly found in the rumen ($\chi2 = 5.03$, df = 5, $P = 0.4127$). There was no significant overlap in terms of predilection sites among the common parasites encountered in wildebeest (Figure 3).

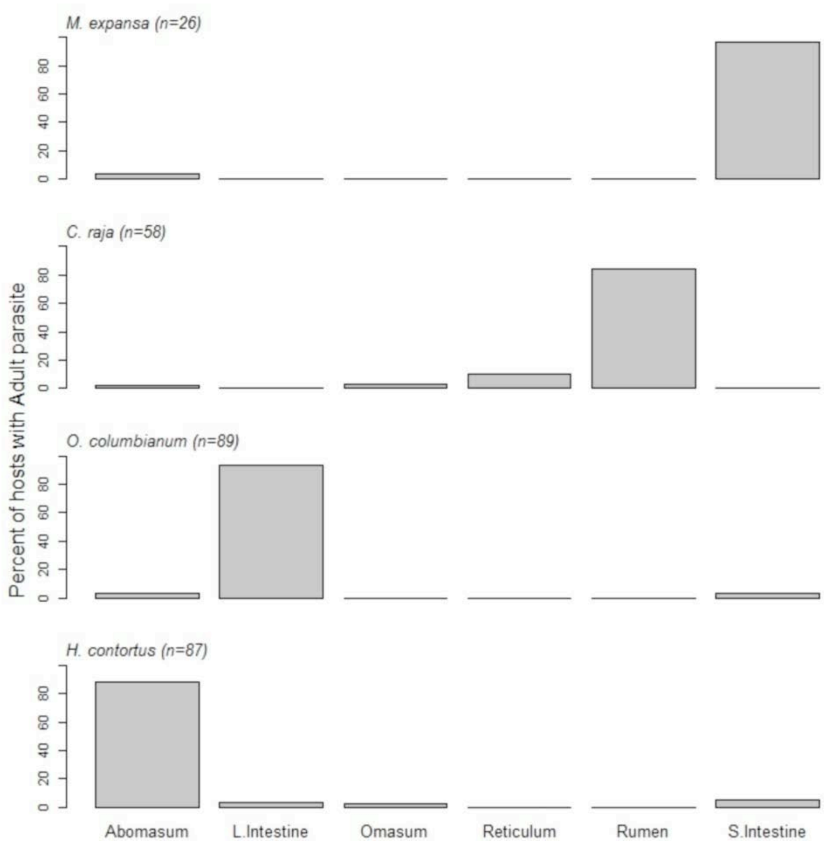

Figure 3. Predilection sites in the gastrointestinal parasites for the common adult helminths infecting migratory wildebeests**.**

Prevalence and co-infection by helminths

We found four species of gastrointestinal helminths from wildebeest including the trematode *C. raja*, the cestode *M. expansa*, the nematodes *H. placei* and *O. columbianum*. Seventy two % (n= 94) of the wildebeests sampled were positive for one or more of the major gastro-intestinal parasites while 27.69% (n=36) of the wildebeests were negative for adult helminths. The overall prevalence of gastrointestinal parasites in wildebeest were high for *O. columbianum* at 46.2% (n=60) and relatively low for *H. placei* at 29.2% (n=38), *C. raja* 20% (n=26) and *M. expansa* 114.6% (n=19). Parasite load (worm burden) was variable among infected wildebeest (Range 1-271 adult parasites). The mean ± (SD) and median worm burden was 13±(34) and 4 worms per individual hosts.

The prevalence of single infections was 38.46%. The prevalence of concurrent infections with two, three and four parasites was 26.15%, 5.38% and 2.31% respectively, while 27.69% of the wildebeests were not infected by any adult helminths. Concurrent infection of hosts with two, three or four parasites was not significantly different from random expectation ($\chi 2$=6.019, df =3, P=0.111).

Diversity and infection load of adult gastro-intestinal parasites and its relation with animal sex, age and crossing time

Parasite prevalence

When dealing with each parasite species separately, the GLM (Generalized Linear Model) poisson with log link analyses revealed that there was a notable effect of age on the prevalence of most parasites in wildebeests (Table 1). The prevalence of *H. placei*, *and M. expansa* was significantly higher in young animals (< 2 year old) comparing to old wildebeests (>3 years old), but the prevalence *of C. raja* was higher in old wildebeest, comparing to the young ones. The migration time (Crossing Area) was also significant, with Mara Bridge higher than Serena Bridge. However, there was no effect of Age, Sex and Migration time on the prevalence of *O. columbianum* (Table 1).

When dealing with all parasite species together, the Generalized linear models revealed that parasite load was higher in juveniles compared to adults and sub-adults. In addition, wildebeests crossing through the Mara bridge had higher parasite loads than wildebeests crossing from the Serena Brigde (Figure 4).

Table 1. GLMs (Generalized Linear Model) saturated models for total parasite load, *Haemonchus placei, Moniezia expansa, Oesophagostomum columbianum* and *Calicophoron raja* as response variable. Crossing Area (representing migration time), Age and Sex of the wildebeest as explanatory variables. Estimate. Std, Error, z-value and Pr (>|z|) are the estimators of coefficient, Standard Error, z-value and significance of the explanatory variables in the different models.

Parasite Load	Estimate	Std. Error	z-value	Pr(>|z|)	Null deviance	df1	Residual deviance	df2	AIC	Explained Deviance
Total load of parasite					3672.2	122	2283	119	2588.6	0.3783
(Intercept)	3.907	0.079	49.532	<2e-16						
Crossing_Area	-2.296	0.061	-37.689	<2e-16						
Age	0.396	0.066	5.979	0						
Sex	-0.031	0.01	-3.195	0.001						
Haemonchus place					146.91	122	130.73	119	138.73	0.1101
(Intercept)	0.697	0.836	0.834	0.404						
Crossing_Area	-1.174	0.74	-1.588	0.112						
Age	-0.223	0.075	-2.995	0.003						
Sex	0.497	0.438	1.136	0.256						
Moniezia expanda					102.412	122	73.603	119	81.603	0.2813
(Intercept)	-16.273	1.924.553	-0.008	0.993						
Crossing_Area	16.685	1.924.553	0.009	0.993						
Age	-0.756	0.299	-2.528	0.012						
Sex	-0.718	0.574	-1.251	0.211						
Oesophagostomum columbianum					170.12	122	167.08	119	175.08	0.0179
(Intercept)	0.538	0.78	0.69	0.49						
Crossing_Area	-0.315	0.711	-0.443	0.658						
Age	-0.091	0.057	-1.606	0.108						
Sex	0.042	0.375	0.113	0.91						
Calicophoron raja										
(Intercept)	-1.965	0.979	-2.007	0.045	124.2	122	89.104	119	97.104	0.2826
Crossing_Area	-2.538	0.94	-2.701	0.007						
Age	0.455	0.106	4.284	0						
Sex	0.786	0.548	1.434	0.152						

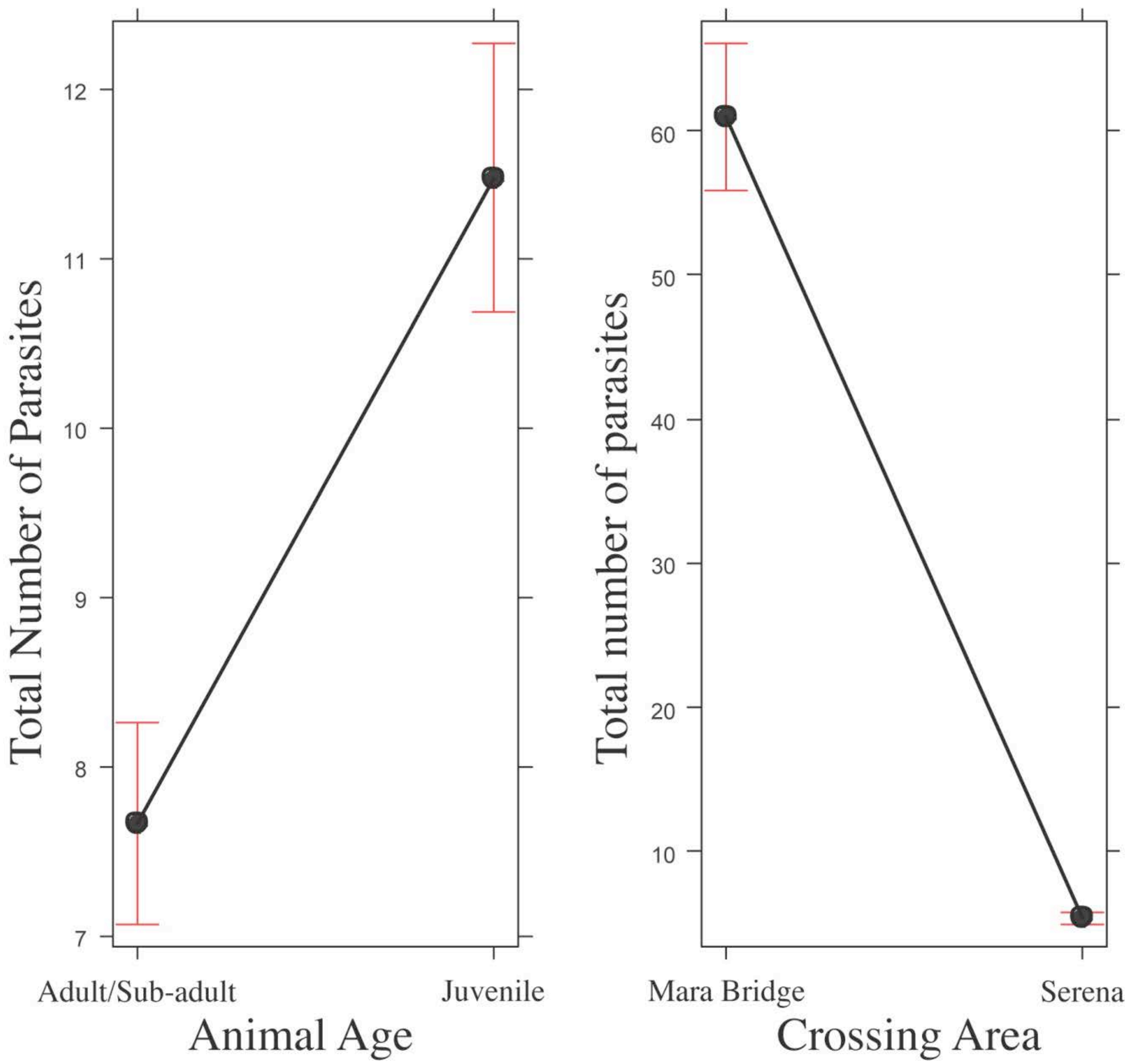

Figure 4. The influence of sex, age (in years) and wildebeest crossing area (representing migration time) on adult parasite load in migratory wildebeests**.**

Parasite load

To test the influence of age, sex and migration time (represented by crossing location) on the number of parasites species, we fitted a logistic regression model to an ordered factor response (number of parasite species). Our model revealed that the number of parasite species in a wildebeest was predicted by animal age and migration time (Table 2). The younger was the animal, the more parasite species it had (Figure 5). Wildebeests sampled from Serena Bridge had higher parasite diversity than wildebeests crossing from Mara Bridge (Figure 4).

Table 2. Coefficients of logistic regression model and intercepts for the each level (ordered response) showing the variation in number of parasite species infecting wildebeests.

Variables	**Coefficients**	**Std. Error**	**t value**	**p value**
Age	-0.1301	0.0532	-2.448	*0.0144*
Sex (Male vs Female)	0.2956	0.34	0.8694	0.3846
Area crossing (Serena vs Mara)	-1.2818	0.6546	-1.958	0.0502
Intercepts				
0|1	-2.6048	0.7417	-3.5118	*0.0004*
1|2	-0.8646	0.7108	-1.2164	0.2238
2|3	0.9618	0.7385	1.3022	0.1928
3|4	2.2565	0.8718	2.5884	*0.0096*

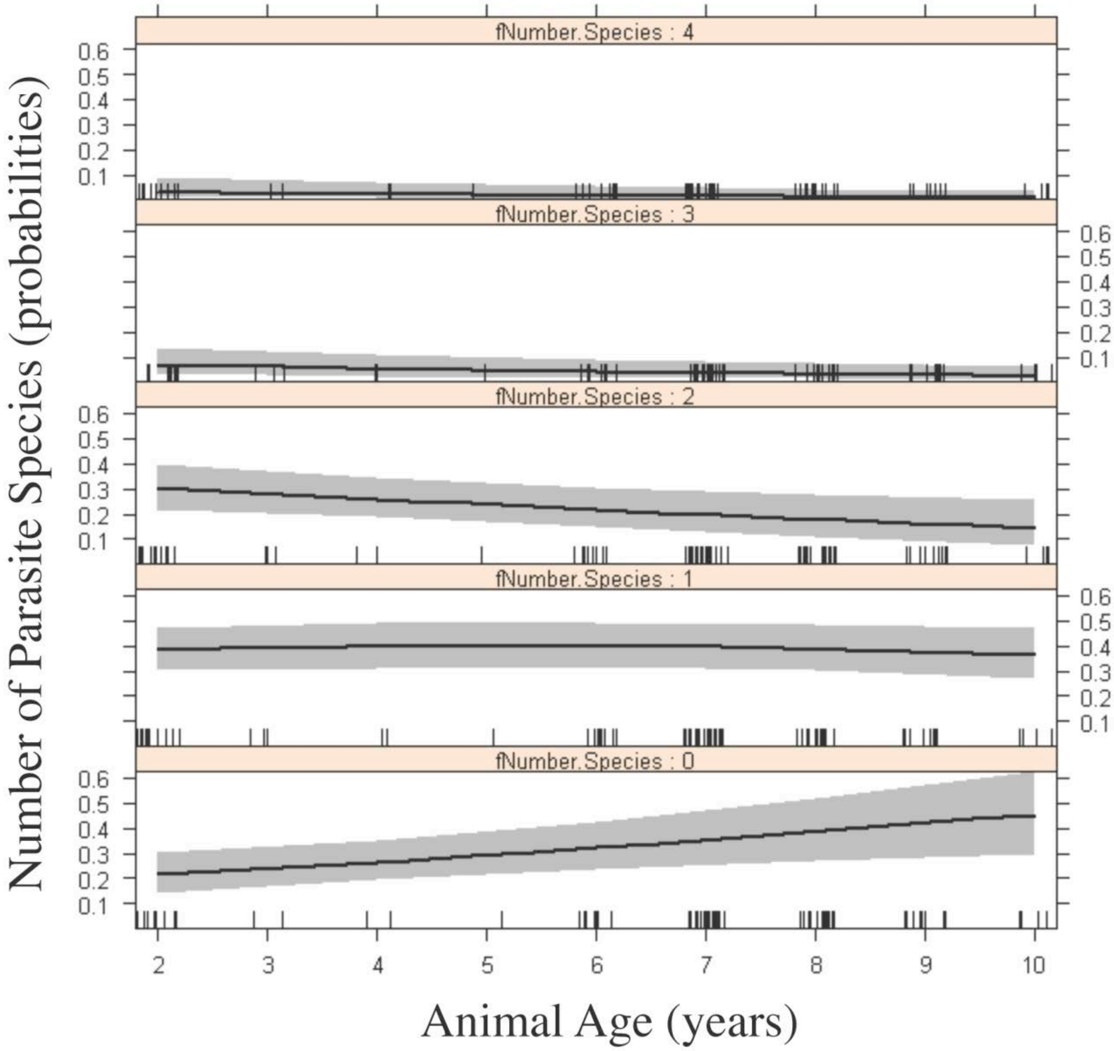

Figure 5. Probability of infection with different species of helminthes as a function of age in wildebeests.

Discussion

Parasite predilection sites and co-infection

Adult parasites recovered from the wildebeest occupied different parts of the gastrointestinal tract with no overlap in predilection sites among parasites. Predilection sites are largely consistent with similar parasites in domestic animals (Sutherland and Scott, 2009, Roeber et al., 2013). In China, *M. expansa*, and *O. columbianum* infecting domestic goats were found predominantly in the small and large intestine respectively, similar to our study (Ma et al., 2014). Contrary to our result, they found *Haemonchus* in the rumen and in the small intestine (Ma et al., 2014).

Co-infections among the four common wildebeest parasites were random association. This result was expected given that the common parasites do not compete for predilection sites in the hosts. Numerous experimental studies have investigated and confirmed the existence of negative and synergistic interactions among parasite (Kloosterman and Frankena, 1988, Kloosterman et al., 1990, Ploeger et al., 1995, Kloosterman et al., 1984, Dobson et al., 1992, Dobson and Barnes, 1995), but there is little empirical evidence to suggest that these interactions occur in the wild.

Prevalence and diversity of gastrointestinal parasites infecting wildebeests

The diversity of the adult helminths infecting migratory wildebeest were surprisingly low (4 species belonging to four genera) and were just a subset of a larger number infecting non-migratory blue wildebeests in South Africa (Junker et al., 2014, Horak et al., 1983). The apparently low diversity could be an artefact of not sampling micro-parasites. However, when we compared gastrointestinal macro-parasites detectable by eye in non-migratory wildebeest in Kruger national park, they had a higher parasite diversity consisting of 12 species from 7 genera (Horak et al., 1983). The low diversity in migratory wildebeests observed in this study is consistent with the hypothesis that migration helps in escaping parasite build up as observed in other migratory mammals (Folstad et al., 1991, Hausfater and Meade, 1982). All the four helminths recovered from the gastrointestinal tract of the wildebeest had a relatively high prevalence and were surprisingly generalist species that commonly infect livestock (Tariq et al., 2008, Dube et al., 2004). The high prevalence of these generalist helminths recovered from migrating wildebeest could result from cross infection from the domestic reservoirs along pastoral landscapes that dominate the wildebeest migratory routes (Dash, 1973, Lone et al., 2011, Junker et al., 2014, Nwosu et al., 1996). The relative rarity of *C. raja* may be related to the scarcity of swampy areas required for the survival of intermediate snail host on the migratory pathways of wildebeest. *O. columbianum* and *H. placei* were the most prevalent parasites in the studied wildebeests signifying their importance in the Masai Mara – Serengeti wildlife areas or in migratory wildebeest.

Effect of age on prevalence and parasites load

The prevalence of *H. placei*, and *M. expansa* was higher in juveniles than in sub-adults or adults. This finding is in agreement with results indicating a higher prevalence of nematodes including *H. placei* and *O. columbianum* in young domestic ruminants compared to adults (Tariq et al., 2008). The significantly higher prevalence of *H. placei*, and *M. expansa* in young animals compared to older ones could be attributed to the fact that juveniles have less protective immunity against these parasites due to limited exposure to helminths compared to older age classes (Kloosterman et al., 1991, Ploeger et al., 1995). As opposite to other parasites, *C. raja* was significantly more prevalent in older animals compared with younger ones. This pattern is typical of the epidemiology of paramphistomes and has been documented in African cattle (Pfukenyi et al., 2005). It suggests that wildebeests do not develop immunity to this parasite or that exposure is limited and animals that are older must have had repeated exposure for infection to occur. The decrease in parasite diversity in older individuals is well documented in helminths and is driven by the immune response elicited by repeated infections (Galvani, 2005, Mutapi et al., 2008).

These results contrasts with findings in other host taxa where parasite diversity is positively correlated to the age (Lo et al., 1998), suggesting that immunity and not exposure is limiting parasite infection patterns in migrating wildebeest (Baird, 1998, Peyerl-Hoffmann et al., 2001).

Effect of migration time (crossing area) on prevalence and parasites load

Interestingly, the wildebeests arriving earlier or crossing through Mara Bridge had a high prevalence and parasite load than those arriving later to the Serena Bridge. This result suggests that early migrants may suffer higher parasitism as a result of nutritional stress in their areas of origin (Holdo et al., 2009).

Effect of sex on prevalence and parasites load

The sex of the hosts was not an important factor influencing the prevalence and parasite load of helminths infection in wildebeests. The lack of sex effect suggests that sex differences in hormonal and/or immunological factors do not play a significant role in helminths transmission between sexes in wildebeests (Wakelin, 1996). Sex differences in parasite prevalence or intensity are usually observed, with males of many species exhibiting higher parasitism than females (Poulin, 1996). A sex bias in parasitism may be due to ecological, behavioural, or physiological differences between males and females (Zuk and McKean, 1996). The lack of sex bias in parasitism might suggest that these factors are not important in wildebeest during the migration, because the energetic demand for migration may be a dominant physiological force homogenizing variation in infection patterns among males and females (Altizer et al., 2011).

Conclusion

The parasites species infecting migratory wildebeest are fewer than those found in non-migratory wildebeest (reported by previous studies) suggesting long distance and massive migration is beneficial as a mechanism of parasite avoidance. Notwithstanding, due to the potential nutritional stress, migration could lead to immune suppression on the early migrant wildebeest. Most parasites recovered from dead migrating wildebeest were generalist parasites known to infect livestock, which is evidence of cross-infection along the migration routes. This result suggest that maintaining migration corridors for wildebeest free from livestock grazing is integral in maintaining long term health and conservation of both livestock and wildebeest, especially the most vulnerable young ones.

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Chapter 5: Results and discussion

Human-Elephant Conflict

During the study period there were more intentional injuries than non-intentional injuries inflicted on elephants by humans. Intentional injuries (active) occur during conflict with humans and their livestock over resources and include spearing, poisoning and poaching for ivory while the unintended injuries (passive) occur when local communities use snares to capture wild animals that do not target elephants specifically. Males were more affected than females in cases of both active and passive injuries. Crop-raiding seems to be sex-biased towards males (Chiyo et al., 2012) and likely hinges on nutritional advantages that can enhance their fitness and reproductive competitiveness (Chiyo, et al., 2011; Corti & Shackleton 2002). This is because sexual selection in a polygynous species such as the elephant is biased towards dominance (Poole, 1989). The propensity of male elephants to raid crops makes them vulnerable to human retaliatory attacks that can cause the high prevalence of injuries observed in males (Obanda et al., 2008) and in our results.

Our results suggest that adult elephants are more likely to be intentionally injured by humans than young elephants. This is probably due to the species' complex social relationships characterized by tightly led matriarchal core units offering security to young elephants that contrast with flexible male units (Archie & Chiyo, 2012). Young male and female elephants remain in the matriarchal herd and at the hint of danger adult females (even from other social units) rush to form a tight ring around the young animals (Dublin, 1983).

This is was not the case of passive injury, which affects adults and young elephants similarly; this is logical given that passive injury is only a question of bad luck and is not specific to any age class. Wire snares, usually set at ground level along animal tracks, are indiscriminate and target multiple species of wildlife (Noss, 1998), and may serve both as a retaliatory weapon and for illegal capture.

Both passive and active injury cases had a significant negative correlation with crop farms (agriculture areas) indicating that elephants are more likely to be injured near crop farms than further away. Our results concur with previous studies that suggest that injury cases were male dominated (Obanda et al., 2008), which reflects the male bias in crop-raiding. A seasonal variation occurred in the number of active injury cases: there were a relatively high number of cases in February and March during the dry period, just before the rainy crop-planting season begins in April–June, which is when elephants are ranging furthest in search of food and water. They are likely to pass through people's homesteads and property and so there are greater chances of conflict with villagers. No seasonal pattern was observed in the case of passively caused injuries indicating that local communities use wire snares with the same intensity during dry and wet seasons. The study observed that, irrespective of injury, elephants tend to concentrate near water bodies. Elephants had a greater possibility of being injured when they were near roads and so most injury cases were reported close to roads. Local communities also played a pivotal role in conservation due to their direct contact with elephants and their ability to inform authorities if they detected injured animals.

Elephant ranslocation

Translocation is often used to reduce human-elephant conflict (Wambwa et al., 2001; Dublin & Niskanen, 2003). However, it has notable risks, which require attention before implementing the process. The common risks include (i) elephant mortality during the translocation process (Pinter-Wollman et al., 2009), (ii) elephants can sometimes reject a release site and return to the source site referred to as homing (Fernando et al., 2012), (iii) increase in elephant injury/death caused by human attacks (Fernando et al., 2012), and (iv) the translocation process is expensive and requires cost-benefit analysis prior to conducting elephant translocation (Grobler et al., 2007). In South Africa the known mortality rate of all elephants translocated since 1994 is only 2.7% (27 known mortalities out of 1,014 elephants). The cause for these deaths vary from the transport truck overturning, elephants with predisposed disease problems, elephants falling accidentally in water or down a cliff after being darted, and failure of equipment (Grobler et al., 2007). In Kenya, all the elephant translocation operations recorded either no mortality or recorded mortality that was lower than 2 %. For example in the first phase of elephant translocation from Narok to Masai Mara in 2011 only one sub-adult female elephant died out of 62 elephants (1.6%). This particular elephant was confirmed to have died of a capture related complication referred to as 'pink foam syndrome' (Gakuya et al., 2003). However, no elephant mortality occurred in the second phase of Narok translocation. Previous elephant translocations in Kenya also recorded very low mortality rates, for instance, the Shimba hills-Tsavo translocation lost three elephants. The causes of these mortalities were sometimes speculatively attributed to rough terrain, equipment failure and long distances of travelling before release.

Elephants can sometimes reject a release site and return to the source site, the behavior has been noted in a number of translocation operations. In Masai Mara, 4 males returned to the source site barely 2 weeks after translocation covering a distance of about 100 kilometres. Chances of elephants returning to source site after translocation decreased with increase in distance. Males were more likely than females to leave the release site. The size of the elephant translocation equipment, because it can restrict access to locations, is an important limiting factor associated with elephant translocation. Financial cost is a major limitation for elephant translocation.

Transport costs and personnel costs remains constant irrespective of how many elephants are translocated per day. However, there is reduction in cost per elephant for translocating an increased number of elephants. Due to high fixed daily expenses, the cost per elephant for moving fewer than 10 individuals is much higher than for moving a higher number of individuals (Grobler et al., 2007).

Migratory wildebeest parasites and livestock

The diversity of the adult helminths infecting migratory wildebeest were surprisingly low (4 species belonging to four genera) and were just a subset of a larger number infecting non-migratory blue wildebeests in South Africa (Junker et al., 2015; Horak et al., 1983). The apparently low diversity could be an artefact of not sampling micro-parasites. However, when we compared gastrointestinal macro-parasites detectable by eye in non-migratory wildebeest in Kruger national park, they had a higher parasite diversity consisting of 12 species from 7 genera (Horak et al., 1983). The low parasites diversity in migratory wildebeests observed in this study is consistent with the hypothesis that migration helps in escape from parasite build up in habitats of resident wildebeest populations as has been observed in other migratory mammals (Folstad et al., 1991; Hausfater and Meade, 1982). All the four helminths recovered from the gastrointestinal tract of the wildebeest had a relatively high prevalence and were surprisingly generalist species that infect many domestic ungulates (Tariq et al., 2008; Dube et al., 2004). The high prevalence of these generalist helminths recovered from migrating wildebeest could result from the high risk of cross infection from domestic ruminants along pastoral landscapes that dominate the wildebeest migratory routes (Dash, 1973; Lone et al., 2011; Junker et al., 2015; Nwosu et al., 1996). The relative rarity of *Calicophoron raja* may be related to the scarcity of swampy areas required for the survival of intermediate snail host on the migratory pathways of wildebeest. *O. columbianum* and *H. placei* were the most prevalent parasites in the studied wildebeests signifying their importance in the Masai Mara – Serengeti wildlife areas or in migratory wildebeest.

The prevalence of *H. placei*, and *M. expansa* was higher in juveniles than in sub-adults or adults. This finding is in agreement with results indicating a higher prevalence of nematodes including *H. placei* and *O. columbianum* in young domestic sheep and goats compared to adults (Tariq et al., 2008). The significantly higher prevalence of *H. placei*, and *M. expansa* in young animals compared to older could be attributed to the fact that juveniles have less protective immunity against these parasites due to limited exposure to helminths compared to older age classes (Kloosterman et al., 1991; Ploeger et al., 1995). Interestingly, the wildebeests arriving earlier or crossing through Mara Bridge had a high prevalence and parasite load than those arriving later to the Serena Bridge. This result suggests that early migrants may suffer heavy parasitemia as a result of nutritional stress in their areas of origin (Holdo et al., 2009).

The sex of the hosts was not an important factor influencing the prevalence and parasite load of helminths infection in wildebeests. The lack of sex effect suggests that sex differences in hormonal and/or immunological factors do not play a significant role in helminths transmission between sexes of wildebeests (Wakelin, 1996). Sex differences in parasite prevalence or intensity are usually observed, with males of many species exhibiting higher parasitism than females (Poulin, 1996).

Adult parasites recovered from the wildebeest occupied different parts of the gastrointestinal tract with no overlap in the gastrointestinal predilection sites among parasites. Predilection sites are largely consistent with similar parasites in domestic animals (Sutherland and Scott, 2009; Roeber et al., 2013). Co-infections among the four common wildebeest parasites were random association. This result was expected given that the common parasites do not compete for gastrointestinal predilection sites in the hosts.

Capitulo 5: Resultados y discusión

El conflicto humano-elefante

Durante el período de estudio hubo más lesiones intencionales que no intencionales causadas en elefantes por los seres humanos. Las lesiones intencionales (activas) ocurren durante el conflicto con los humanos y sus recursos de ganado, incluyendo alancear, envenenamiento y caza ilegal de marfil, mientras que las lesiones no intencionales (pasivas) ocurren cuando las comunidades locales utilizan trampas para capturar animales salvajes no dirigidas específicamente a los elefantes. El factor predominante parece ser el factor sexo, sesgado hacia los machos (Chiyo et al., 2012) que probablemente dependerá de las ventajas nutricionales que puedan mejorar su aptitud y competitividad reproductiva (Chiyo, et al., 2011; Corti y Shackleton 2002). Esto es porque la selección sexual en una especie poligínica como el elefante está sesgada hacia la dominancia (Poole, 1989). La predominancia de los elefantes macho los hace más vulnerables a ataques o represalias humanas causando una alta prevalencia de lesiones (Obanda et al., 2008) observada en nuestros resultados.

Nuestros resultados sugieren que los elefantes adultos son más propensos que los jóvenes a ser lesionados intencionalmente por los seres humanos. Esto es probablemente debido a las complejas relaciones sociales de las especies caracterizadas por unidades de base matriarcal, que ofrecen seguridad a los elefantes jóvenes contrastando con unidades masculinas más flexibles (Archie y Chiyo, 2012). Los elefantes jóvenes, tanto machos como hembras, permanecen en el seno materno y, al indicio de posibles amenazas, las hembras (incluso de otras unidades sociales) se apresuran formar un anillo consistente alrededor de los animales jóvenes (Dublín, 1983).

Sin embargo, en el caso de las lesiones pasivas, afectan de igual forma a elefantes jóvenes y adultos; esto es lógico dado que la lesión pasiva es solo una cuestión de mala suerte y no es específico para cualquier clase de edad. Las trampas de alambre generalmente situadas a nivel de suelo a lo largo de las huellas de animales, que son indiscriminadas y de múltiples especies de fauna silvestre (Noss, 1998), pueden servir como un arma de represalia y de captura ilegal.

Ambos casos de lesión, activa y pasiva, mantenían una correlación negativa significativa con granjas de cultivos (áreas de agricultura) que indica que los elefantes son más propensos a ser heridos cerca de granjas de cultivo que en zonas más alejadas. Nuestros resultados coinciden con estudios anteriores que sugieren que los casos de lesiones fueron mayoritariamente en machos (Obanda et al., 2008), lo que refleja el sesgo masculino en los ataques en cultivos. Se produjo una variación estacional en el número de casos de lesiones activas: hay un número relativamente alto de casos en febrero y marzo durante el período seco, justo antes de las lluvias en cultivos de siembra que comienzan en abril y junio, cuando los elefantes se van más lejos en busca de alimento y agua. En este periodo son más probables los ataques en granjas y propiedades de personas y, por lo tanto, hay mayor posibilidad de conflicto con los ciudadanos. No se ha detectado una relación entre el patrón estacional y las lesiones pasivas, lo que indica que las comunidades locales utilizan trampas de alambre con la misma intensidad durante las temporadas secas y húmedas. El estudio observó que, independientemente de la lesión, los elefantes tienden a concentrarse cerca del agua. Los elefantes tenían una mayor posibilidad de ser heridos cuando se encontraban cerca de los caminos, por lo que en la mayoría de los casos las lesiones fueron registradas cerca de las carreteras. Las comunidades locales también jugaron un papel fundamental en la conservación debido a su contacto directo con los elefantes y su capacidad para informar a las autoridades si detectaban animales heridos.

La translocación en elefantes

La translocación se utiliza a menudo para reducir el conflicto humano-elefante (Wambwa et al., 2001; Dublín y Niskanen, 2003). Sin embargo, tiene notables riesgos que requieren atención antes de implementar el proceso. Los riesgos comunes incluyen (i) la mortalidad del elefante durante el proceso de translocación (Wollman Pinter et al., 2009), (ii) los elefantes a veces pueden rechazar un lugar libre y volver al sitio de origen conocido como migración de vuelta (Fernando et al., 2012), (iii) el aumento de lesiones o muertes en elefantes causadas por ataques humanos (Fernando et al., 2012), y (iv) el proceso de translocación es caro y requiere un análisis sobre el coste-beneficio antes de realizarlo (Grobler et al. 2007). En Sudáfrica la tasa de mortalidad de los elefantes por translocación desde 1994 es solo el 2.7% (27 fallecidos de 1.014 elefantes). La causa de estas muertes varían desde el vuelco de transporte de camiones, problemas de enfermedades recurrentes, caídas accidentales en el agua o por un acantilado de los elefantes despues de recibir el dardo anestésico (Grobler et al., 2007). En Kenia, todas las operaciones de desplazamientos de elefantes registran tasas de mortalidad inferior al 2% o incluso no se aprecia. Por ejemplo en la primera fase del desplazamiento de elefantes de Narok a Masai Mara en 2011 solo murió una hembra sub-adulta de un total de 62 elefantes (1.6%). Se ha confirmado que este elefante en particular pudo haber muerto por la captura, provocando una complicación conocida como "síndrome de espuma rosa" (Gakuya et al., 2003). Sin embargo, no se produjo mortalidad en la segunda fase de translocación de Narok. Anteriores desplazamientos de elefantes en Kenia también registran las tasas de mortalidad muy bajas, por ejemplo, la translocación de colinas-Tsavo registró solo la pérdida de tres elefantes. Las causas de los fallecimientos fueron en ocasiones especulativamente atribuidas a terrenos accidentados, problemas del equipo y largas distancias de viaje antes de su puesta en libertad.

Los elefantes a veces pueden rechazar un lugar en libertad y volver al sitio de origen, el comportamiento se ha observado en un gran número de operaciones de translocación. En Masai Mara, cuatro machos volvieron al sitio de origen tras dos semanas desde la translocación, atravesando una distancia de aproximadamente 100 kilómetros. La posibilidad de que los elefantes volvieran al sitio de origen después de la translocación disminuyó al aumentar la distancia. Los machos tenían más probabilidad de abandonar el lugar en libertad que las hembras. El tamaño de los equipos de translocación de elefantes, el cual puede restringir el acceso a los lugares, es un importante factor limitante asociado con el desplazamiento del elefante. El coste financiero es una limitación importante para la translocación del elefante.

Los gastos de transporte y personal permanecen constantes independientemente de cuántos elefantes son translocados por día. Sin embargo, hay una reducción en el coste por elefante para la translocación de un mayor número de elefantes. Debido a altos gastos diarios fijos, el coste por elefante para mover menos de 10 individuos es mucho más elevado que para mover un mayor número (Grobler et al., 2007).

Los parásitos de los ñúes migratorios y del ganado

La diversidad de los helmintos adultos que infectaban a los ñúes migratorios eran sorprendentemente bajos (cuatro especies pertenecientes a cuatro géneros), solo un subconjunto de un gran número de ñúes azules no migratorios infectados en Sudáfrica (Junker et al., 2015; Horak et al., 1983). La aparentemente baja diversidad podría ser a consecuencia de no realizar un muestreo de micro-parásitos. Sin embargo, cuando comparamos macro-parásitos gastrointestinales detectados a simple vista en ñúes no migratorios en el Parque Nacional Kruger, se obtuvo una mayor diversidad, doce especies de siete géneros (Horak et al., 1983). La baja diversidad observada en este estudio en parásitos de ñúes migratorios es consistente con la hipótesis de que la migración ayuda a emigrar al parásito, acumulándose en hábitats de poblaciones de ñúes residentes, como se ha observado en otros mamíferos migratorios (Folstad et al., 1991; Hausfater y Meade, 1982). Los cuatro helmintos recuperados en el tracto gastrointestinal de los ñúes presentaban una prevalencia relativamente alta y eran sorprendentemente especies generalistas que infectaban a muchos ungulados domésticos (Tariq et al., 2008; Dube et al., 2004). La alta prevalencia de estos helmintos generalistas obtenidos de los ñúes migratorios puede provocar un alto riesgo de infección en los rumiantes domésticos a lo largo de las tierras de pastoreo que dominan las rutas migratorias de los ñúes (guión, 1973; cruzada Lone et al., 2011; Junker et al., 2015; Nwosu et al., 1996). La relativa rareza de *Calicophoron raja* puede deberse a la escasez de zonas pantanosas, necesaria para la supervivencia del caracol hospedador intermediario en las vías migratorias de ñúes. *O. columbianum* y *H. placei* fueron los parásitos más prevalentes en los ñúes estudiados, lo que manifiesta su importancia en las áreas de fauna salvaje del Masai Mara-Serengeti o en ñúes migratorios.

La prevalencia de *H. placei* y *M. expansa* fue más elevada en los juveniles que en subadultos o adultos. Este hallazgo está de acuerdo con resultados que indican una mayor prevalencia de nematodos incluyendo *H. placei* y *O. columbianum* en ovejas y cabras domésticas jóvenes comparados con adultos (Tariq et al., 2008). La significativamente mayor prevalencia de *H. placei* y *M. expansa* en animales jóvenes en comparación con los más viejos podría atribuirse al hecho de que los menores tienen una menor inmunidad contra estos parásitos debido a la limitada exposición a helmintos comparado con las clases de edad más avanzada (Kloosterman et al., 1991; Ploeger et al., 1995). Curiosamente, los ñúes que llegaban antes o cruzaban a través del Puente de Mara tenían una alta prevalencia y mayor carga parasitaria que los que llegaban más tarde al Puente de la Serena. Este resultado sugiere que los primeros migrantes pueden sufrir una dura parasitemia como resultado del estrés nutricional en sus áreas de origen (Holdo et al., 2009).

El sexo de los hospedadores no fue un factor determinante en la prevalencia ni en la infección por carga parasitaria de helmintos en ñúes. El efecto de la ausencia del factor sexo sugiere que las diferencias de sexo en los factores hormonales o inmunológicos no juegan un papel importante en la transmisión de helmintos entre sexos de ñúes (Wakelin, 1996). Generalmente se observan diferencias de sexo en la prevalencia o intensidad con los machos de muchas especies, exhibiendo mayor parasitismo que las hembras (Poulin, 1996).

Los parásitos adultos encontrados en los ñúes que ocupaban las diferentes partes del tracto gastrointestinal no se solapaban con los parásitos alojados en zonas gastrointestinales preferentes. Los parásitos de las zonas preferentes son en gran medida similares a los encontrados en animales domésticos. (Sutherland y Scott, 2009; Roeber et al., 2013). Las coinfecciones entre los cuatro parásitos de ñúes comunes fueron asociadas al azar. Este resultado se esperaba dado que los parásitos comunes no compiten por zonas gastrointestinales preferentes en los hospedadores.

Chapter 6: Conclusions

Human-Elephant Conflict

1. Our results suggest that local communities inflict active injuries on elephants in retaliation for the destruction of their properties or deaths.

2. Injured elephants are unlikely to risk remaining close to human settlements.

3. Local communities may also negatively affect elephants by their use of snares to capture other wild animals as bush meat. Nevertheless, local communities do play positive roles as key informants in the early detection of injured elephants.

Elephant translocation

4. One of the most effective tools to mitigate HEC is elephant translocation. Between 1995 and 2012, KWS translocated 559 elephants, the average translocation distance was 325 km, and the average mortality was 2.3%.

5. There was significant decline in HEC cases in Kenya as a result of elephant translocations. For instance, there has been a significant annual decline in HEC in Narok during the two-year period (2011–2012) after translocation, ($p<0.05$). A total of 518 HEC cases were reported in the year 2010 while only 236 conflict cases in the year 2012.

Migratory wildebeest parasites and livestock

6. Most parasites recovered from dead migrating wildebeests were generalist parasites known to infect livestock and suggest that wildebeests share helminths with livestock in pastoralist dominated landscapes during migration or may be wildebeests transmit parasites to livestock in the migratory corridors.

7. The prevalence of *H. placei*, and *M. expansa* was higher in juveniles than in sub-adults or adults.

8. The predilection gastrointestinal sites chosen by the four parasites were quite similar to sites occupied in domestic ruminants indicating that the parasites could cause a similar effect or impact in wildebeests as they do in domestic ruminants.

9. Sex had no effect on the prevalence of the four parasites found in the migratory wildebeests. This was rather quite unique for wildebeests since sex differences in parasite prevalence or intensity are usually observed commonly, with males of many species exhibiting higher parasitism than females.

Capitulo 6: Conclusiones

Conflicto humano-elefante

1. Nuestros resultados sugieren que las comunidades locales influyen en las lesiones activas sobre elefantes en represalia por la destrucción de sus propiedades o por muertes del ganado.

2. Es improbable que los elefantes heridos corran el riesgo de permanecer cerca de los asentamientos humanos.

3. Las comunidades locales pueden también afectar negativamente a los elefantes por el uso de trampas para capturar otros animales salvajes como carne de monte. Sin embargo, las comunidades locales desempeñan un papel positivo como informador clave en la detección temprana de elefantes heridos.

Translocación de elefantes

4. Una de las herramientas más eficaces para mitigar la HEC es la translocación del elefante. Entre 1995 y 2012, KWS translocó 559 elefantes, la distancia de desplazamiento promedio fue de 325 km, y la mortalidad promedio fue de 2.3%.

5. Hubo una reducción significativa en los casos de HEC en Kenia como resultado de translocaciones de elefantes. Por ejemplo, ha habido un importante descenso anual en HEC en Narok durante el período de dos años (2011 – 2012) después de la translocación ($p < 0.05$). Se notificaron un total de 518 casos HEC en el año 2010 mientras que solo 236 casos de conflicto en el año 2012.

Los parásitos de los ñúes migratorios y del ganado

6. La mayoría de los parásitos encontrados de ñúes migratorios muertos eran generalistas conocidos por infectar al ganado, y sugiere que los ñúes presentan helmintos similares a los del ganado en pastoreo localizados en los paisajes dominantes durante la migración o que los ñúes transmitan parásitos al ganado en los corredores migratorios.

7. La prevalencia de *H. placei* y *M. expansa* fue mayor en juveniles que en sub-adultos o adultos.

8. Las zonas gastrointestinales preferentes elegidas por los cuatro parásitos fueron bastantes similares a los lugares ocupados por los rumiantes domésticos, indicando que los parásitos podrían causar un efecto similar o un impacto en ñúes como en el caso de los rumiantes domésticos.

9. El factor sexo no tuvo efecto sobre la prevalencia de los cuatro parásitos que se encuentran en los ñúes migratorios. Esto fue algo absolutamente único para los ñúes desde que se establecieran diferencias entre el factor sexo y la prevalencia o intensidad parasitaria comunmente observadas con machos de muchas especies que exhiben mayores tasas de parasitismo que las hembras.

PERSPECTIVES

1. The concentration of actively injured elephants closer to crop farms and roads and away from settlements suggests that injured elephants are likely to risk repeat raids near the road network. In order to minimize the number of elephant injury cases, there should be limited human settlements, crop farming and road network in elephant conservation areas.

2. The fact that many injured elephants preferred to stay away from human settlements suggests that the presence of crop farms and roads in elephant areas is a high risk factor driving the incidence of HEC, the prevalence of injury cases and the spatial distribution of injured elephants.

3. More efforts should be made to safeguard elephants in parts of the Masai Mara ecosystem, especially in close proximity to crop farms and roads, and attempts should also be made to raise awareness in local communities and encourage them to play their parts in saving the elephants. This would reduce elephant injuries and mortalities related to the human-elephant conflict and save the cost of chemical immobilization and treatment of affected elephants.

4. One of the most effective tools to mitigate HEC is translocation, this thesis can guide the future decision-making in the use of translocation as a mitigation option for HEC in Kenya and elsewhere.

5. The reported decline in cases of human-elephant conflict was attributed to translocation of the 106 elephants from Narok to Masai Mara National Reserve. In Mwea National reserve HEC declined to nil after a successful elephant translocation to Tsavo East National park. A well-maintained electric fencing controlled the few remaining elephants. This implies that translocation and fencing combined can significantly reduce cases in most of the elephant ranges bordering community settlements.

6. Wildebeests because of their long distance migration may act as conduits for disease spread to livestock and other ungulates. They also face a greater risk of acquiring helminths from pastoralist dominated landscapes during migration. The potential risk of disease transmission to wildebeest or

livestock will require studies on the genetic similarity of parasites that are shared between wildebeest and livestock in order to determine the direction of disease transmission in livestock.

7. The association of parasite infection with age suggests with increasing exposure, older wildebeests appear to acquire protective immunity against these parasites. Age-based prevalence can provide insight into the existence of host-acquired immunity and age-dependent variation in host exposure to these parasites and guide the control strategy.

8. Sex bias in parasitism in many species is attributed to ecologic, behavioral, or physiologic differences between males and females. This phenomenon might be lacking in free-ranging migratory wildebeests since there was no sex bias in parasitism in the Mara-Serengeti population of migratory wildebeests.

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