EISSN: 2707-0425

East African Journal of Science, Technology and Innovation, Vol. 1 (4): September 2020.

Comparative analysis of the typology, seasonality and economic cost of human-wildlife conflict in Kajiado and Laikipia Counties, Kenya

[1,2*]MANOA D O., [2]MWAURA F., [3]THENYA T., [2]MUKHOVI S.

[1]Born Free Kenya, P.O. Box 1519-00502, Nairobi, Kenya.
[2]Department of Geography & Environmental Studies P. O. Box 30197-00100, University of Nairobi, Nairobi, Kenya.
[3]Wangari Maathai Institute of Peace and Environmental Studies, P. O. Box 30197-00100, University of Nairobi, Nairobi, Kenya.
***Corresponding author**: manoadavid4@gmail.com

Abstract

Human –wildlife conflicts (HWC) affect the social-economic aspects of millions of people across the world and is one of the most important challenges facing wildlife conservation. Long-term data collection provides an opportunity to critically understand HWC trends and enable wildlife stakeholders to create evidence-based solutions for co-existence of people and wildlife. We used Kenya Wildlife Service (KWS) data for the 2010-2018 period to analyse trends in typology, seasonality and economic costs of HWC in Kajiado and Laikipia Counties in Kenya. A total of 953 HWC reported cases in the two counties were analysed. Wildlife threats to human life, crop damage and livestock predation were the common form of HWC, contributing 65.7% (n=626), 21.7% (n=207), and 7.7% (n=73) respectively. Apart from livestock predation (t=2.431; P=0.028) all other types of HWC did not show any significant differences in the two counties over the nine-year period. Elephants were responsible for the highest conflict cases (79%, n=753) followed by baboons (6.9%, n=66). Elephants contributed to the highest human fatality and injuries (43%, n=10); while snakes and buffalo were second, each contributing to 17% (n=4) of the total cases. Majority of the HWC occurred in the dry season months of July (n=114), January (n=99) and October (n=96). The overall trend indicated increasing HWC cases over the 9 years in both counties. The analysis of economic cost of HWC showed that a total of 64.09 hectares of crops were damaged in 2010-2018, with 70% of the cases reported in Kajiado County. In terms of predation, Kajiado lost livestock worth KES 1,785, 000 (U$ 16,780.53) while Laikipia lost KES 407,000 (U$ 3826.15). This study provides empirical evidence that can be used to develop strategies for mitigating HWC based on types, seasons and conflict species.

Keywords: *Human-wildlife conflict; Economic losses; Typology; Trend; Kajiado; Laikipia.*

Introduction

Human-wildlife conflict (HWC) is one of the critical challenges facing conservation across the globe, and as a result, it has captured the attention of many stakeholders including researchers, policy makers, managers and practitioners (Glikman, *et al*., 2019). Traditionally, HWC has been more intense in developing world where people depend largely on livestock and agriculture for subsistence and income (Eniang *et al*., 2011). However, according to Messmer (2019) communities living in urban neighbourhoods are also increasingly affected by HWC. This can be attributed to the encroachment of wildlife habitats by human settlements as population continue to grow across the globe. HWC often manifests

Cite as: Manoa *et al., 2020 Comparative analysis of the typology, seasonality and economic cost of human-wildlife conflict in Kajiado and Laikipia Counties, Kenya East African Journal of Science, Technology and Innovation 1(4)*

Received: 22/06/20
Accepted: 28/07/20
Published: 24/09/20

itself as crop damage, livestock predation, human death and injuries, property damage and disease transmission. For instance, crop raiding by white-tailed deer, bear and ground hogs has been documented in Maryland (United States Department of Agriculture, 2012). Additionally, disease transmission has been noted, for example, Hudson *et al.* (2002) reported the spread of tuberculosis vectors (*Mycobacterium bovis*) by badgers (*Meles meles*) in United Kingdom, since 1950s. HWC also results to a range of direct economic costs that vary in trend and magnitude of economic losses. In China, brown bears in Qinghai Province attacked and killed nine people and injured five, between 2014 and 2017 causing house break-in damages approximated to US$ 4.03 million (Dai *et al*. 2019). Similarly, in Russia, Kudrenko *et al*. (2020) affirms that between 1932 and 2017, brown bear attacked 386 people engaged in different activities including livestock herding, fishing, and hiking. In USA, wildlife strikes, especially bird aircraft strike hazards (BASH) in the aviation industry resulted to an annual economic loss of US$ 957 million between 1990 and 2012 (Dolbeer *et al*, 2013). At the same time, the Centre for Diseases Control (CDC) reported that an average of 7500 people were bitten by a poisonous snake each year in the USA, with up to five deaths annually (CDC, 2018).

The social costs of HWC are associated with losses that are usually uncompensated, temporally delayed, or of psychosocial nature (Ogra, 2008) and are classified as opportunity, transaction and health costs (Ogra, 2008, Barua *et al*. 2013; Manoa *et al*. 2020). In a study undertaken in Bostwana, 72% of participants indicated that they were unsafe in rural villages because of the risk and fear of encountering elephants, and had to forego daily livelihoods activities such as fuelwood collection, farming and livestock herding (Mayberry *et al*. 2017). Additionally, several studies have reported widespread livestock predation among communities living near protected areas (Patterson *et al*., 2004; Holmern *et al*., 2007; Manoa & Mwaura, 2016).

The types and magnitude of HWC is diverse in Africa, where community livelihoods and wildlife habitats are often intertwined in most ecosystems. In Tanzania, for instance, crocodiles attacked 51 people between 2003 and 2012 around Lake Rukwa and Momba River (Zakayo, 2014). In the same period, 52 cattle, 23 goats and10 dogs were killed by crocodiles in the area. According to Naughton *et al.* (1999), farmers in Uganda lost about 61% of their crops in fields around Kibale National Park, amounting to losses of up to US$60 per household between February and August 1999. In addition, Ngene and Omondi (2009), reported losses amounting to KES 15, 034,610 (US$ 208,814) around the Marsabit National Park and Reserve in Kenya which was attributed to crop raiding by elephants between August 2004 and July 2005. Another study analysed the trends in compensation for HWC in Narok County, between 2001 and 2017 (Mukeka *et al*. 2019). Various other studies have been conducted in Kenya, to document the economic loss of HWC (e.g. Ngene & Omondi, 2000; Muriuki *et al*, 2017). Many of these studies focus on either one species or one dimension of conflict such as livestock predation or crop raiding (for example Sitati, 2003; Patterson *et al.* 2004; Graham, 2007; Kamweya *et. al*. 2012; Siteinei *et al*. 2014).

Compensation for HWC losses has led to negative impacts to Kenya's economy by diverting financial resources that would otherwise be used for conservation and economic development. Kenya Wildlife Service (KWS) continues to pay huge sums of money for HWC loss compensation. For instance, in 2018, KES 35.6 million (US$ 332585.95) was used to pay for compensation of human deaths and injuries arising from wildlife attacks between 2013 and 2016 in Taita-Taveta County alone (Mg hoi, 2018). According to KWS (2019), between 2014 and 2017, Kenya reported 452 human death; 4,555 human injury; 5,073 crop damages; 3,012 livestock predation and 33 property destruction, all amounting to KES 3.4 billion (US$ 317,638,264).

As population increases and the demand for agricultural land intensifies, more people are moving into wildlife areas, especially rangelands, thereby leading to increased competition for space and resources between people and wildlife (County Government of Kajiado (CGK), 2018). Rangelands such as Kajiado and Laikipia Counties are now increasingly occupied by farmers and livestock keepers with continued expansion of human settlements, which is bringing people and wildlife into frequent contact (CGK, 2018; Manoa *et al*., 2020). This is exacerbated by

climate change that is escalating water scarcity and causing vegetation cover reduction, leading to increased HWC. As a result, the mitigation measures put in place to minimise HWC are severely challenged and require continuous application of new strategies. The formulation of such strategies to reduce the economic losses both to farmers and to the government requires continuous research and monitoring in order to support evidence-based mitigation decision making. This includes documentation on the typology, trend and magnitude of HWC. Long-term data collection provides an opportunity for deeper understanding of HWC that can help create evidence-based solutions for people and wildlife. Studies that use existing long-term HWC data are scarce, yet many of such data exists in various databases and repositories. The aim of this study was to address the existing data utilization gap by making use of the 2010-2018 records to undertake the following: a) analyse the typology of HWC including the identification of the most problematic wildlife species b). assess and compare the HWC seasonality trends in Kajiado and Laikipia counties, and c) to estimate the magnitude of economic loss associated with HWC.

Materials and Methods

Study Areas

Kajiado County (21,292.7 km²) is situated between longitude 36˚, 5' and 37˚, 55' East and between latitude 1˚ 10' and 3˚, 10' South while Laikipia County (8,696 km²) lies between latitudes 0º 18" South and 0º 51" North and between longitude 36º 11" and 37º 24' East in southern and central regions of Kenya, respectively. They constitute two of the forty-seven counties in Kenya, and are in semi-arid areas. (**Figure 1**).

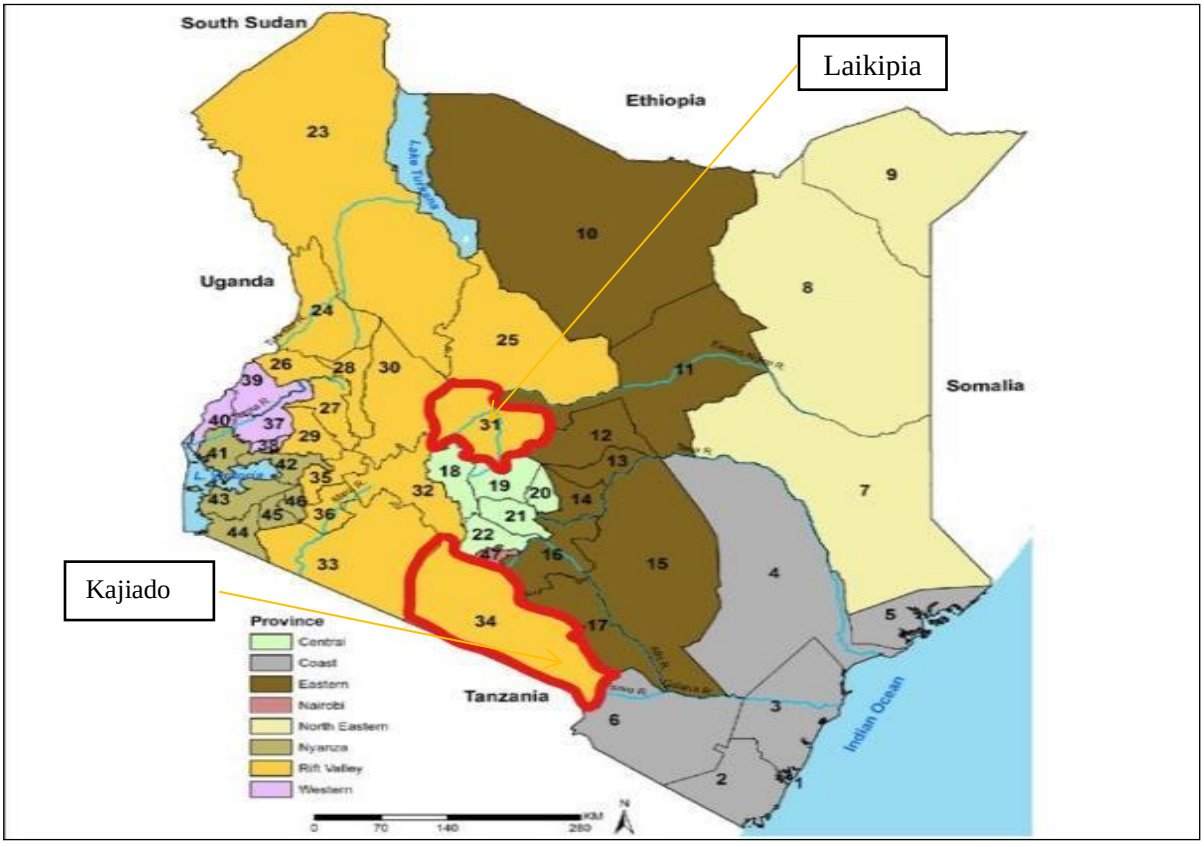

Figure 1: *Map of Kenya with Laikipia and Kajiado Counties (Source: Modified from Macharia et al., 2019)*

Laikipia County is located close to the equator while Kajiado is situated in southern Kenya bordering Tanzania. The two are part of the Kenya rangelands which dominate the country (>80%) and have some of the highest wildlife densities in Kenya.

The two counties are associated with lowland plateaus, with the lowest altitude in Kajiado at about 500m at Lake Magadi and the highest is 2500m in the Ngong Hills (County Government of Kajiado (CGN), 2018). Laikipia County, on the other hand, has an altitude of between 1,500 m to 2,600 m above sea level. The two counties are associated with bimodal rainfall pattern, with rainfall in Kajiado occurring in October-December (short rains) and March-May (long rains). The annual mean rainfall fluctuates from 300mm to 1250, while the mean annual temperature varies from 10^{o} C to 34^{o}C. The annual rainfall in Laikipia ranges between 400mm and 750mm, while average annual temperature varies from 16^{o}C and 26^{o}C (County Government of Laikipia - CGL, 2018).

The two counties are similar in several ways. Both are located on the leeward edge of the highest summits in Africa with Kajiado lying to the north of Mt Kilimanjaro (5,895m) and Laikipia to the north-west of Mt. Kenya (5,199m). The two are important wildlife conservation areas, which host several state, community and wildlife protected areas. Key wildlife species in the two areas include large savanna species like giraffe (*Giraffa spp*), elephant (*Loxodonta africana*), buffalo (*Syncerus caffer*), bushbuck (*Tragelaphus scriptus*), impala (*Aepyceros melampus*), zebra (*Equus burchelli*), lion (*Panthera leo*), leopard (*Panthera pardus*), African wild dog (*Lycaon pictus*) among other species. Wildlife movements are common between Kajiado and adjacent areas including Mt. Kilimanjaro and Longindo in Tanzania as well as the Loita Plains and the Masai Mara to the north-west. In Laikipia County, wildlife migrates between Mt. Kenya, Aberdare ranges and the northern counties of Samburu and Isiolo.

According to Kenya National Bureau of Statistics (KNBS, 2019), Kajiado County hads 1,117,840 people, with a population density of 51 persons per square kilometre, and 316,179 households as compared to Laikipia County, which has 518,560 people with a population density of 54 person per square kilometre and 149,271 households. Livestock production is a major source of livelihood in both counties. In recent years, the two counties have experienced rapid encroachment by agrarian communities from the high population density counties in the humid highlands of central Kenya, thereby creating a serious problem in terms of wildlife conservation (GoK, 2013a). This is common in the more humid areas such as Ngong, Loitokitok, Nkuruman, Marmanet and Ngarua. The main crops grown are maize, beans, onions, Irish potatoes, tomatoes, capsicum, watermelon, cow peas, vegetables and bananas (CGL, 2018). In recent years, most of the wildlife migratory corridors and dispersal areas have been blocked off by increased farming activities, fencing and introduction of human settlement, thus increasing human wildlife conflicts. Kajiado County, which falls under Nairobi Metropolitan, is experiencing rapid urbanization due to its proximity to Nairobi, the capital city of Kenya.

Materials and Methods

Data sources and indicators

Data was obtained from the Devolution and Community Service Department at KWS headquarters in Nairobi. KWS is the state agency mandated by the Wildlife Conservation and Management Act 2013 (WCMA 2013) to manage wildlife in Kenya since its establishment in 1989. KWS manages about 8 per cent of the total landmass of the country (580,367 km²) in state protected areas (22 National Parks, 28 National Reserves and 5 National Sanctuaries). Apart from its presence in the protected areas, KWS has stations in all the 47 counties of Kenya. Each station is mandated to collect and collate data on HWC and this is relayed to the KWS headquarters for tallying. The secondary data used in this study was based on the HWC complaints received from people in the Kajiado and Laikipia Counties.

The secondary archival data was accessed through a formal application for authorization in accordance with the official protocol as stipulated in WCMA 2013, Section 62 (1). The HWC digital records for Kajiado and Laikipia counties were filtered from the KWS database with a total 1013 HWC records for the 2010-2018 period. The records included a wide range of HWC issues such as human injury, human

death, crop damage, property damage and livestock predation among others. The data was extracted digitally from the archival database in a standard form for each entry. The standard entry parameters for each HWC case included date of occurrence, location, nature of conflict, magnitude of damage, and action taken.

Data pre-processing involved the identification and removal of repeated HWC cases as well as records that were outside the two target counties. The data filtering culminated in to 953 valid cases, which were extracted for detailed analysis against the study objectives. The variables that were examined in the data included the location and date of HWC incidents, HWC wildlife species, types and number of affected livestock, human attacks, type and acres of crops damaged. The magnitude of economic losses incurred through HWC was estimated through the market price method by considering the quantity of crop and livestock affected against their unit price in Kajiado and Laikipia markets. The economic magnitude of human deaths and injuries was based on the official rates provided in Schedule II of the wildlife legal framework in Kenya (WCMA 2013) which recommends KES 5,000,000 (US$ 46963.89) compensation for human death and an average of KES 2,500,000 (US$ 23491.52) for injury.

Data analysis

Statistical analysis was done using Statistical Package for Social Scientist (SPSS, version 20). Human attacks were classified into deaths, injuries and threats. Cases of HWC over the years were summarized in graphs and tables. T-test statistic was used to test any significant difference between the magnitude of HWC in Kajiado and Laikipia Counties. To determine the money losses from HWC, the mean affected number of cattle, shoat and donkey were multiplied by the average market price in Kajiado and Laikipia Counties. The common crop prizes were obtained from the Cereal Growers Association (http://cga.co.ke/2019/03/29/best-maize-varieties-kenya/). Statistical significance level was limited to 95% Confidence Level.

Results

HWC typology

The HWC incident magnitude analysis showed that out of 953 valid cases, Kajiado county accounted for 524 (55%) incidents while Laikipia county had 429 (45%) cases which amounted to a marginal incident difference of less than 100 cases despite the over 12,000 km^2 geographic area difference. The typology analysis showed that the HWC profile varied significantly over the years in both counties with wildlife threat to humans, crop destruction and livestock predation contributing to 65.7% (n=626), 21.7% (n=207) and 7.7% (n=73) of incidents, respectively (Figure 2).

The trend analysis indicated a rise in the number of HWC cases between 2015 and 2018, with the highest cases reported in 2017 (n=221). The results of the student t-test showed there was no significant difference in the rates of crop raiding ($t=0.80554$, $d.f=15$, $p=0.433091$), human attacks ($t=0.823804$, $d.f=16$, $P<0.05$), property damage ($t=1.6344$, $d.f=5$, $P=0.161213$) in Kajiado and Laikipia Counties between 2010 and 2018. Contrary, livestock predation differed significantly ($t=2.43122$; $P=0.028056$) between the two counties over the 9 years of data analysis.

Dominant HWC species

The analysis showed that the elephants contributed 79% (n=753) of the HWC cases in the two study counties, followed by baboons, 6.9% (n=66) (Table 1). Other wildlife species, which included zebra, monkey, snake, giraffe, crocodile, eland, and hartebeest contributed to 2.8% of the total HWC cases in Laikipia (n=8) and Kajiado (n=19).

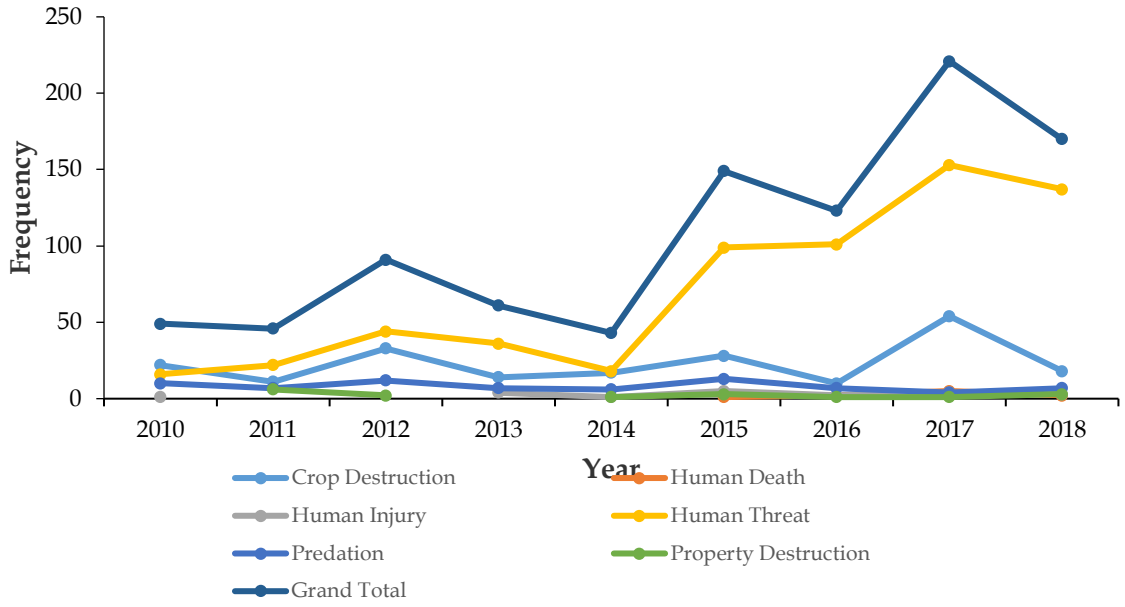

Figure 2: *Trends in typology of HWC in Kajiado and Laikipia Counties, 2010-2018*

Table 1: *Species and their contribution to HWC in Laikipia and Kajiado Counties*

Species	Kajiado	Laikipia	Average incidents per year	Overall contribution to HWC (%)
Baboon	46	20	8.25	6.9%
Buffalo	11	18	3.63	3.0%
Elephant	396	357	94.13	79.0%
Spotted hyena	23	6	3.63	3.0%
Leopard	7	23	3.75	3.1%
Lion	18	1	2.38	2.0%
Others	19	8	3.38	2.8%

HWC seasonality trend

The occurrence of HWC showed remarkable seasonal variation in both counties over the 9 years with the dry season having more incidents (54%, $\bar{X}$=43.25±10.21, n=519) compared to the wet season ($\bar{X}$=36.17±9.17). However, an independent student t-test indicated that the variation was not statistically significant (t=1.34853; df=22; P<0.05). Majority of the HWC incidents were reported in July (n=114), followed by January (n=99) and October (n=96) as shown in Figure 3. The least cases of HWC occurred in November (n=37). The analysis showed that Kajiado had a monthly average of 43.67 incidents, while Laikipia had 35.75 incidents (Figure 4). The seasonal analysis of HWC incidents by species showed that the elephant was the most troublesome animal especially during the months of January, July and October (Figure 5).

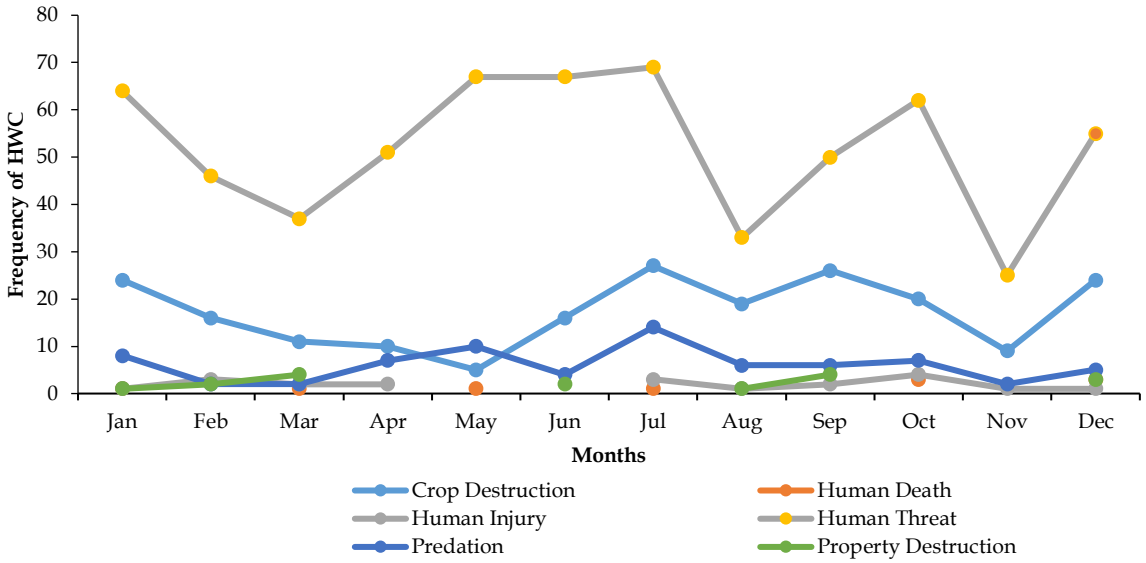

Figure 3: *Seasonal patterns in HWC incidents in Kajiado and Laikipia Counties (2010-2018)*

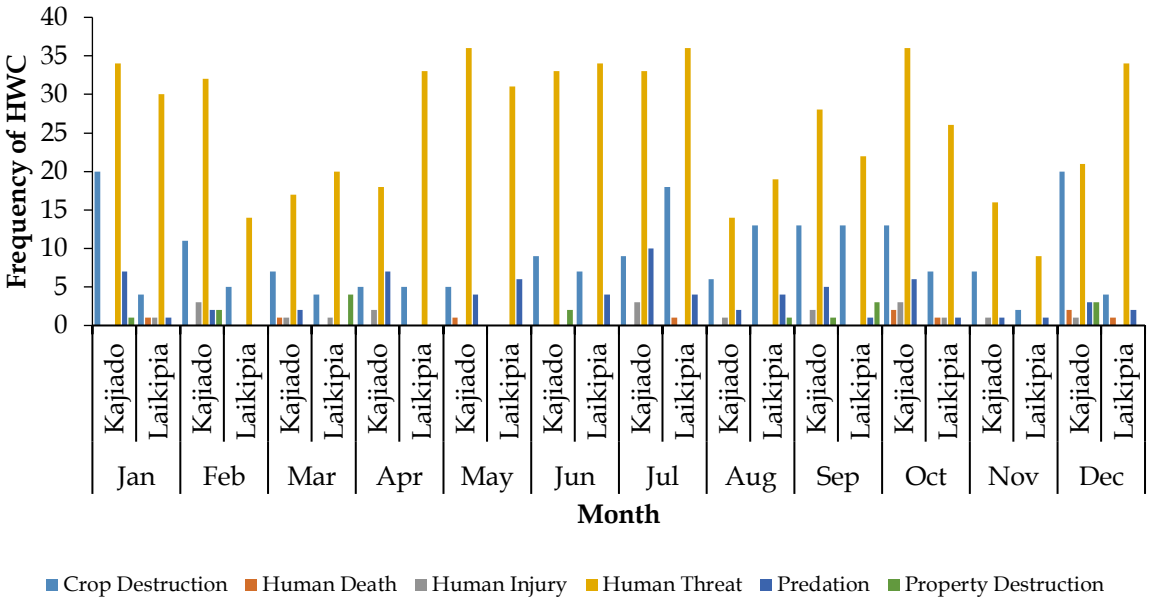

Figure 4: *Comparative seasonal occurrence of HWC between Kajiado and Laikipia Counties (2010-2018)*

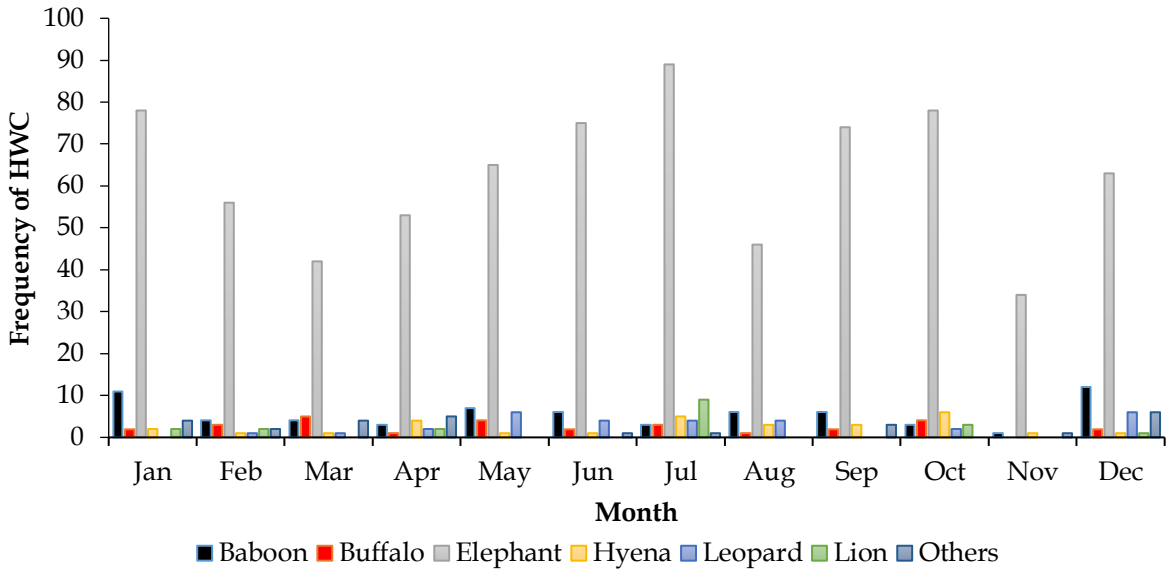

Figure 5: *Wildlife species and the seasonal variation in HWC in Kajiado and Laikipia Counties*

Economic magnitude of HWC losses

Crop losses

Although, there was a range of crops damaged by wildlife, we used the most common crops (maize and beans) in the two counties to determine the magnitude of HWC in terms of acreage and monetary loss. Where mixed cropping of maize and beans were damaged, we worked on assumption that each crop occupied 50% of the land raided. A total of 64.09 hectares of crops were damaged in 2010-2018, with 70% of the cases reported in Kajiado County (**Figure 6**). The total highest number of crop acres damaged was recorded in 2017 (18.4 hectares) while the lowest in 2010 (1.34 hectares).

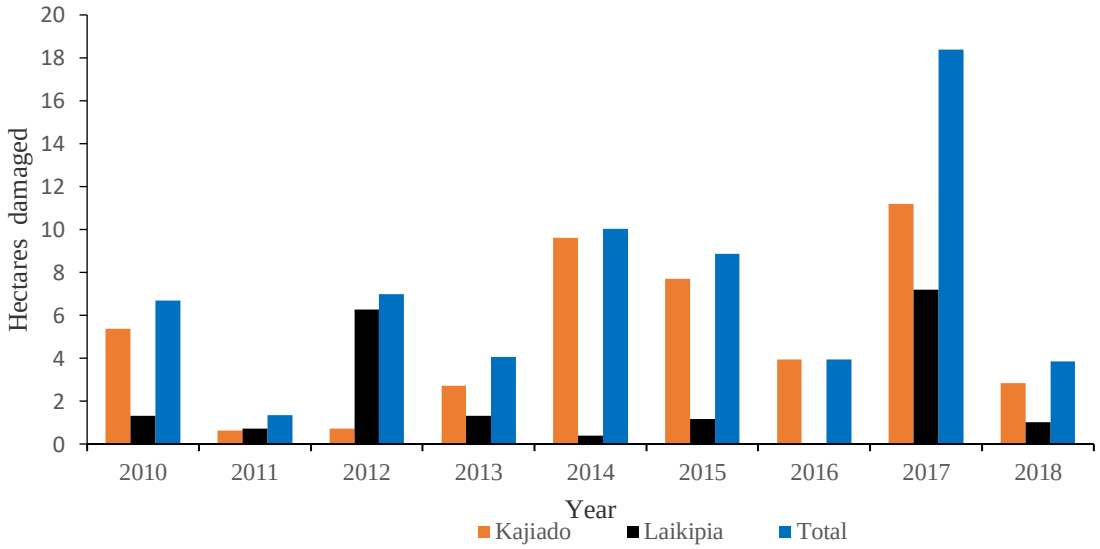

Figure 6: *Hectares of crops damaged by wildlife in 2010-2018 in Kajiado and Laikipia Counties*

Based on the 2019 crop market prices by the Cereals Growers Association of Kenya (CGAK) at KES 2500 and KES 8,000, respectively for maize and beans and the average production per hectare of 80.31 bags and 21 bags respectively, the crop losses were computed as shown in **Table 2**. The findings showed that Kajiado County had the highest average loss of maize and beans, averaging KES 344,635.42 (US$3,248.83) and KES 90,666.76 (US$ 854.70) per year, respectively.

Table 2: *Magnitude of maize and beans loss through wildlife destruction*

Crop	County	Hectares damaged	Av. Production per Hectare	No. of bags	Av. Market Price/90kg bag	Total loss in KES and US$	Av. Loss per year
Maize	Laikipia	6.88	80.31	552.5	KES 2500	KES 1,381,250.00 (US$9375)	KES 153,472.22(US$1446.76)
	Kajiado	15.45	80.31	1240.6875	KES 2500	KES 3,101,718.75 (US$29,239.44)	KES 344,635.42 (US$3,248.83)
Beans	Laikipia	4.86	21	102	KES 8000	KES 816,000.00 (US$7692.31)	KES 90,666.76 (US$854.70)
	Kajiado	6.58	21	138.125	KES 8000	KES 1,105,000.00 (US$10416.67)	KES 122,77.78 (US$1157.41)

Livestock predation losses

Although livestock losses were generally lower than crop losses, the former occurred throughout the 9 years in both Kajiado and Laikipia Counties compared to the seasonal nature of the latter. Livestock attacks were categorised according the affected animals, namely cattle, shoat (sheep and goat), and donkey. The average market price for cattle was obtained from the local markets in Kajiado (Kimana, Loitokiotok and Ilbisil) and Laikipia (Nanyuki, Rumuruti and Dol Dol). The average price for cattle was KES 40,000(US$377.07), compared to KES 5,000 (US$ 47.13), for shoats and KES 12,000 (US$ 113.12) for donkeys. The estimation of the economic magnitude of HWC losses showed that Kajiado incurred the highest shoat (181) and cattle (22) loss between 2010 and 2018. The total financial loss of livestock in Kajiado was KES 1,785,000(US$ 16826.92) compared to KES 407,000(US$3836.73) in Laikipia County

Table 3: *Livestock Loss in Laikipia and Kajiado Counties, 2010-2018*

Livestock	Kajiado Amount in KES	Laikipia Amount in KES
Cattle	880,000 (U$8295.63)	KES 120,000 (US$1131.22)
Donkey	-	KES 12,000 (US$ 113.12)
Shoats	KES 905,000 (U$8531.30)	KES 275,000(2592.38)
Total	KES 1,785,000 (US$16826.92)	KES 407,000(US$ 3836.73)

Majority of the livestock losses in Kajiado were attributed to attacks by the hyena (39%, n=19), baboon (20%, n=10 and lion (20%, n=10). In Laikipia, the leopard contributed to the highest predation (50%, n=19). The findings showed that the baboons were third (21%, n=15) in contributing to livestock loss in Kajiado and Laikipia Counties (**Figure 7**).

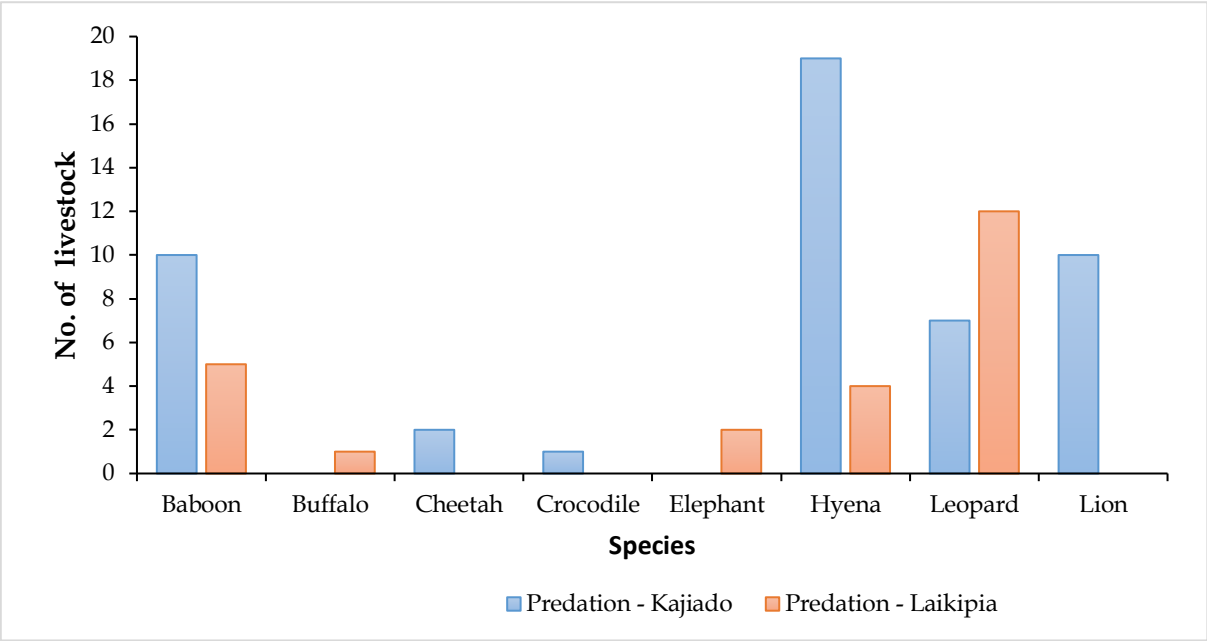

Figure 7: *Livestock loss to different species of wildlife in Laikipia and Kajiado counties*

Human death, injury and related threats

The findings showed that human attacks in the two counties increased over the years, with the highest peak in 2017 (**Figure 8**). Kajiado County had the highest number of human death (6) and injuries (21) cases. This was equivalent to a total compensation claim of KES 30,000,000 (US$ 282246.68) for human deaths and KES 52,500,000 (US$ 493931.69) for human injuries. The responsible wildlife included the elephants which was associated with the highest combined fatality and injuries (43%, n=10) followed by snakes and buffaloes with each contributing to 17% (n=4) of the total cases.

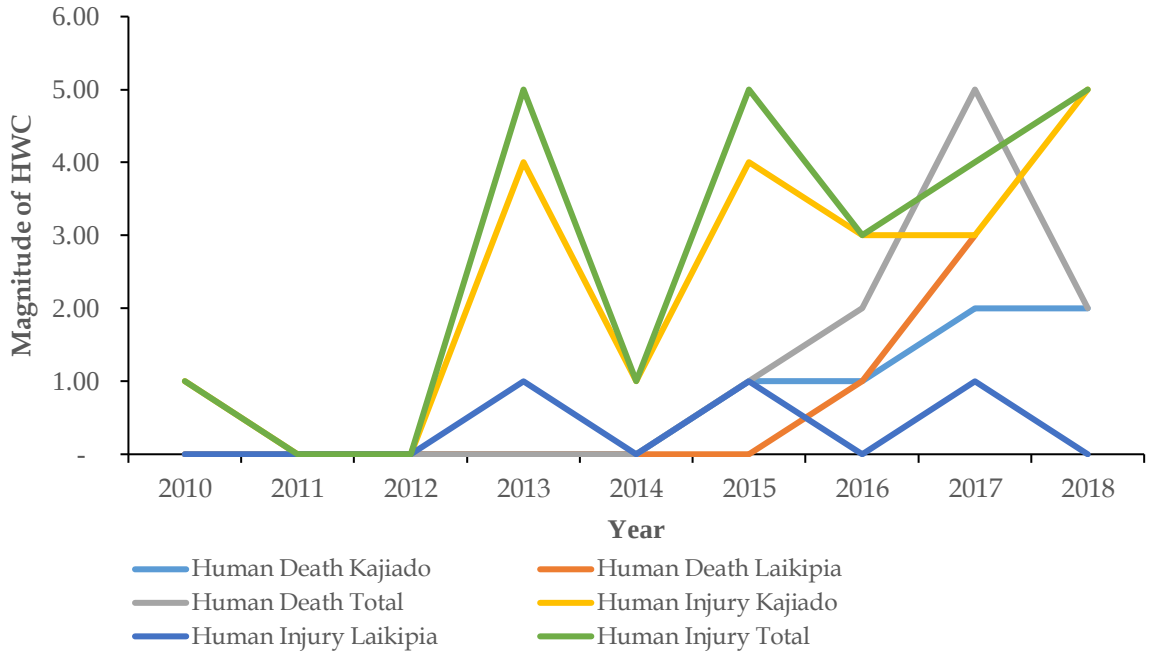

Figure 8: *Trends in the magnitude of human fatality and injuries*

Discussion

HWC typology

HWC cases rose between 2015 and 2018 in both Kajiado and Laikipia Counties. This may be attributed to the fact that the WCMA 2013 came to effect in 2014, thereby opening doors for HWC victims to solicit compensation for visible cost losses as listed in Schedule 3 of the Act. This could have prompted many people suffering from HWC to report their cases to KWS, with the hope of being paid. The government abolished compensation for crops in 1989 due to widespread corruption in the compensation and shortage of funds (KWS, 1996). The WCMA 2013 provides for better compensation rates for wildlife damages. For example, human death amount rose from KES 30,000 (US$ 282.30) to KES 5,000,000 (US$ 47050.25), while livestock and crop loss are paid at the prevailing market rates.

Dominant HWC species

Elephant contributed to the highest number of HWC. The large contribution of elephant to the HWC dilemma can be attributed to its large body size, extensive territorial space that requires large quantities of food (average of 150 kg of vegetation per day, IUCN, 2020) and water (up to 190 l/day). The elephants also have a large home range, which is estimated to be between 5200 km^2 and 7790 Km^2 in Amboseli landscape (Ngene *et al.*, 2017). According to Shaffer *et al*. (2019), a typical family herd of African elephants (~5–20 individuals) has a home range size of 11–500 km, which explains why elephants must traverse beyond protected areas thereby escalating the HWC problem.

The findings showed that the elephant also contributed to high incidents of human attacks and threats over the 9-years period. The high rank of the elephant as a key HWC is attributed to its wide habitat range. Hoare, (1999); Blanc *et al.*, (2003) observe that, "the elephant's range in Kenya covers some 109,071 km^2, of which almost 80% is outside protected areas. However, this can also be attributed to the general fear by people for elephants based on the historical experiences especially with regard to loss of human life. A study by WWF (2020) noted that, "while many people in the north regard elephants with affection and admiration, the animals often inspire fear and anger in those in the south to who share their land". Records in Kenya show that 50–120 problem elephants are shot by wildlife authorities each year and that about 200 people died in human-elephant conflict between 2010 and 2017 (Mariki *et al*., 2015). This is in agreement with the findings of the study in South Africa by Taruvinga and Mushunje (2014) which established that societies, which reside close to elephants share greater obliteration perceptions, while the global community, which resides far from elephants, subscribes to conservation perceptions. This study established that baboons were the second in contributing to HWC in Kajiado and Laikipia counties. The study established that baboons are widely distributed in in different habitats within the Laikipia and Kajiado Counties ranging from grassland, woodland, and bushland to human settlement areas. Because of their omnivorous nature, the baboons were found to raid both crops as well as attacking livestock. It was established that the baboons also attacked human beings and destroyed properties in the study area. Their diverse attacks could be the reason why baboon HWC cases were relatively high compared to other species, except the elephant. The findings in this study are similar to those by Letiva (2018) observations in villages around Naibunga conservancy in Laikipia County, where baboons were found to break into peoples' houses, take food, destroy property and scare people thereby preventing them from fetching essential commodities such as water and firewood. Our findings are also similar to Syombua (2013) study of HWC in Taveta-Taveta County, which revealed that the elephants and baboons largely contributed to the HWC compared to other species in the area such as hyenas and buffalos.

HWC seasonality trends

The number of HWC cases varied over the seasons during the 9 years period in both Kajiado and Laikipia Counties. The seasonal patterns in HWC incidents can be associated to the traditional wildlife movements across the conservation areas into human settlements in search of food and water during the dry season. A similar study conducted in Narok County which is also characterized by high wildlife density, indicated that HWC also peaked during the dry season, which was attributed to herbivores preference for crops due to the higher palatability and nutritional value compared to their normal pasture during the dry season (Mukeka *et al*. 2019). In addition, Gross *et al*. (2018) emphasises that crop damage by herbivores is largely influenced by the availability of the crop, type, season and, and the

phenological stage of the crop. The high-peak occurrence for crop destruction by wildlife in the wet season is similar to findings in other studies. The study on human-elephant conflict in North Benga (India) by Naha *et al* (2019) showed that the frequency of conflicts increases during the rainy season, which also coincides with the harvest of major agricultural crops such as wheat, maize and paddy.

Contrary to crop raiding, livestock predation had a peak towards the end of wet season (May) and dropped at the onset dry season (June) before rising again in July in both counties. Several studies including those by Beattie *et al.* (2020) and Robertson *et al*. (2019) established that livestock predation varies depending on prey availability, catchability and seasonality. The study by Robertson *et al*. (2019) showed that livestock attacks by predators in in Botswana were more frequent and severe during the dry season. However, livestock predation also depends on the prey species, livestock herding method and the type of livestock enclosing shed or kraal. In Tanzania, a study conducted by Kissui *et al*. (2019) indicated that livestock predation by hyena was more severe during the wet season due to the migratory nature of the herbivores during that season. Similar observations were made by Manoa and Mwaura (2016) in a study conducted in the Amboseli region of Kajiado County where the severity of livestock predation by wildlife prey was associated with the availability of pasture and water. Manoa and Mwaura (2016) further noted that the effort needed by predators to capture wild prey was much higher during the wet seasons thereby leading to a shift towards the livestock as an alternative "easy" prey, which consequently heightened the level of HWC.

Economic magnitude of HWC cost

Crop losses

Generally, Kajiado County had high number of crop hectares damage compared to Laikipia Counties but peak loss occurred in 2012 and 2017, respectively for Kajiado and Laikipia. The difference for the higher crop losses can be attributed to the geographic area, population and climatic conditions of the two counties. The land size of Kajiado (21,871.1 km^2) is almost twice that of the Laikipia County (9,532.20 km^2). Similarly, Kajiado has almost twice the population of Laikipia (KNBS, 2019) while the average annual rainfall in Kajiado is between 450 mm and 1454 mm compared to 400 mm and 750 mm in Laikipia. As such, more people could have been exposed to HWC in Kajiado than Laikipia due to the higher agricultural potential in the former than the latter. Secondly, with the new wildlife law (WCMA 2013) in place, more people in Amboseli could have taken up the initiative to report the HWC cases than those in Laikipia County. This is because Kajiado County has organizations (such Big Life Foundation and Amboseli Trust for Elephant) that have operated HWC consolation schemes for over 10 years. Residents in Kajiado could be more conversant with the compensation process than those in Laikipia County. Thirdly, most of the Laikipia County is dominated by large scale private ranches with most properties secured using live electric fence as opposed to Kajiado, where wildlife still freely moves between Amboseli National Park and community group ranches, generally increasing the chances of conflicts.

Livestock predation losses

The findings showed that the main cause for livestock losses in Kajiado County was similar to those of other studies conducted in the area, where hyena was found to kill more livestock compared to other species (Muriuki *et al*, 2017; Manoa & Mwaura, 2016; Okello *et al*. 2014a). However, our finding slightly differs from the study by Mukeka *et al*. (2018) in the Tsavo and Maasai Mara regions, where cases of livestock predation by lions were the highest followed by the spotted hyena and the leopard. The findings on the baboon are similar to those of a study conducted in Gokwe communal land in Zimbabwe, which revealed that baboons attacked young sheep and goats contributing to 52% of the reported cases (241), compared to lion (34%) and leopard (12%). Another study conducted by Ogada *et al*. (2003) in Samburu, established that baboons contributed to 4% of the total livestock loss in the area. In Kenya, Harding (1974) observed that between 1970 and 1971, baboons in the Gilgil area of Nakuru County caught and fed on the smaller or younger individuals of other wildlife species such as dik-dik, impala and steenbok.

Human death, injury and related threats

The number of human attack cases in Kajiado and Laikipa based on the KWS secondary data were lower compared the the average annual national figures of 142 deaths and 1011 injuries reported between 2007-2016 by Mukeka *et al*. (2019). Gitonga (2019) ireported that up to 352 people were killed by wildlife while 2,180 injured in

Kenya between 2014 and 2017. The difference between our findings and the national level records is suprising because Kajiado and Laikipia are among the HWC hot spots identified by KWS. However, the difference can be interpreted according to the view by Okello *et al*. (2014b) who attributed the low number of reported cases to the sensitive nature of human death and injuries cases, and therefore one incident can be one too many. Our findings are also contrarly to the findings of a countrywide study by Mukeka *et al* (2019) in terms of the key wildlife species associated with human death and injury who attributed 43.1% of the total number of deaths to snakes followed by elephants (18.8%). The difference can be attributed to the wider distribution of snakes within most of the seven ecological zones compared to the elephants which are not common in some areas.

Although human attacks were fewer than crop raiding and livestock predation, Okello *et al*. (2014b: pg 471) acertains that "death and injury of people elicits stronger and lasting resentment against wildlife in general because of human social ties and support system". This results to hostility, negative attitude and perception toward wildife conservation, partuclary when HWC compensation is delayed. Although, the Government of Kenya spent KES 1.2 billion to settle HWC claims for the 2014-2017 period, a total of 4,722 cases were deferred due to lack of 'relevant documents' and funds (Gitonga, 2019). This is likely to increase anger, hostility and animosity by people towards problematic wildlife especially those who have already filed their complaints and monetary compensation claims for losses incurred. This can escalate the problem of retaliatory killings of wildlife. Yet, for people and wildlife to coexist, community support is vital (Nyhus, 2016).

Conclusion

The study shows that wildlife threat to human life, agricultural crop raids and livestock predation are among the most common types of HWC in the rangeland counties of Kenya. The problem of crop raiding is associated with elephants and baboons, while livestock predation is largely attributed to the hyenas, leopards and baboons. The number of human fatalities and injuries is relatively low due to many years of co-existence between societies and pastoral communities in the rangelands through which people have come to understand wildlife behaviour and lead cautious lives. However, a single case of human attack can further worsen the HWC particularly when the compensation process is delayed or not paid at all.

HWC is more pronounced in dry season during which rangeland wildlife migrate to their dispersal areas in search for water, green pastures and prey. Consequently, clear knowledge on species-specific seasonal movements can help in minimizing HWC by putting in place the required response team to counter the most problematic wildlife. It also provides wildlife management authorities with necessary information required for enriching distressed wildlife habitats with resources such as water to reduce wildlife movement into human settlements. However, all these details are likely to be affected by the impacts of climate change. It is therefore imperative to document how the climate change is shaping the HWC concerning different ecosystems and species.

The study showed that the economic magnitude of HWC losses is largely dependent on the types of wildlife species in an area in relation to the human population and land use practices. However, a review of the current wildlife policy and regulations in Kenya is urgently necessary in order to ensure effective strategies for compensation for HWC damages. Studies on alternative compensation mechanisms (e.g tax rebates, land rate payment waiver, free healthcare and university education, etc) are also needed given the current situation where the government appears to be straining in terms of meeting the annual compensation budget. One of the major lessons emerging from the study is the situation in Laikipia where fewer HWC cases were reported despite high concentration of wildlife. This raises the question of whether fencing and the practice of keeping wildlife in private ranches and community conservancies is a suitable mitigation for HWC in rangeland areas.

Acknowledgements

We are grateful to Kenya Wildlife Services for providing the HWC data for Kajiado and Laikipia Counties. We also thank the Born Free Foundation for providing a grant for the study. This study was approved by National Commission for Science, Technology & Innovation (*Permit No. NACOSTI/P/18/38627/23786*).

References

Barua, M., Bhagwat, S. A. and Jadhav, S. (2013). The hidden dimensions of human–wildlife conflict: Health impacts, opportunity and transaction costs. Biological Conservation, *157*, 309–316.

Beattie, K., Olson, E. R., Kissui, B., Kirschbaum, A., and Kiffner, C. (2020). Predicting livestock depredation risk by African lions (Panthera leo) in a multi-use area of northern Tanzania. *European Journal of Wildlife Research*, *66*(1), 11.

Blanc, J. Thoules, C. Hart, J., Dublin, H., Douglas-Hamilton, I., Craig, C., Banes, R., (2003). African elephant status report 2002. An update from the African Elephant Database. IUCN/SSC African Elephant Specialist Group. IUCN, Gland Switzerland and Cambridge, UK.

Centers for Disease Control and Prevention (CDC). 2018. Venomous snakes. Centers for Disease Control and Prevention, Atlanta, Georgia, USA. Retrieved from: https://www.cdc.gov/niosh/topics/snakes/default.html

Cereals Growers Association of Kenya (2019). Best Maize varieties. Retrieved from: http://cga.co.ke/2019/03/29/best-maize-varieties-kenya/

County Government of Kajiado (2018). County integrated development plan 2018-2022.

County Government of Laikipia (2018). County integrated development plan 2018-2022.

Dai, Y., Hacker, C. E., Zhang, Y., Li, W., Li, J., Zhang, Y., ... and Li, D. (2019). Identifying the risk regions of house break-ins caused by Tibetan brown bears (*Ursus arctos pruinosus*) in the Sanjiangyuan region, China. *Ecology and Evolution*, *9*(24), 13979.

Dolbeer, R.A., Wright, S.E., Weller, J., and Begier, M.J. (2013). Wildlife Strikes to Civil Aircraft in the United States, 1990–2012. Federal Aviation Administration National Wildlife Strike Database Serial Report Number 19.

Eniang, E. A., H. M. Ijeomah, G. Okeyoyin, and A.E. Uwatt. (2011). Assessment of human–wildlife conflicts in Filinga range of Gashaka Gumti National Park, Nigeria. Production Agriculture and Technology Journal 1, 15–35.

Gitonga, A. (2019). Government pays Sh1.2B to victims of wildlife attacks. The Standard Newspaper. Retrieved from: https://www.standardmedia.co.ke/lifestyle/article/2001356681/state-pays-sh1-2b-to-wildlife-attack-victims .

Glikman, J. A., Frank, B., and Marchini, S. (2019). Human-wildlife interactions: Multifaceted approaches for turning conflict into coexistence. In B. Frank, J. A. Glikman, & S. Marchini (Eds.), Human-wildlife interactions: Turning conflict into coexistence (pp. 439–452). Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108235730

GoK (2013a). Sector Plan for Drought Risk Management and Ending Drought Emergencies. Second Medium-Term Plan, 2013-2017.

GoK (2013b). Wildlife Conservation and Management Act, 2013.

Graham, M. D. (2007). Coexistence in a Land Use Mosaic?: Land Use, Risk and Elephant Ecology in Laikipia District, Kenya (Doctoral dissertation, University of Cambridge).

Gross, E. M., Lahkar, B. P., Subedi, N., Nyirenda, V. R., Lichtenfeld, L. L., and Jakoby, O. (2018). Seasonality, crop type and crop phenology influence crop damage by wildlife herbivores in Africa and Asia. *Biodiversity and Conservation*, *27*(8), 2029-2050. Is it cited?

Harding, R. S.O. (1974). The Predatory Baboon, Expedition Magazine, 16,2. Penn Museum. Retrieved from: http://www.penn.museum/sites/expedition/?p=2457

Hoare, (1999). Determinants of human - elephant conflict in a land- use mosaic. Journal of Applied Ecology 36(5): 1365-2664.

Holmern, T., Nyahongo, J., and Røskaft, E. (2007). Livestock loss caused by predators outside the Serengeti National Park, Tanzania. Biological, 135, 534-542.

Hudson, P. J., Rizzoli, A. P., Grenfell, B. T., Heesterbeek, J. A. P., & Dobson, A. P. (2002). Ecology of wildlife diseases.

IUCN (2020). SSC Groups Directory of Specialist Groups, Red List Authorities, Task Forces of the Species Survival Commission (SSC). Retrieved from https://www.iucn.org/ssc-groups/mammals/african-elephant-specialist-group/faq

Kamweya, A. M., Ngene, S. M., & Muya, S. M. (2012). Occurrence and level of elephant damage to farms adjacent to Mount Kenya forests: implications for conservation. *Journal of Biology, Agriculture and Healthcare*, *2*(5), 41-55.

Kenya National Bureau of Statistics (KNBS) (2019). 2019 Kenya Population and Housing Census Results Volume 1: Population by County and Sub-County. Government of Kenya.

Kenya Wildlife Service. (1996). Wildlife-human conflicts, sources, solutions and issues. Retrieved from https://www.safariweb.com/kws/human-wildlife-conflicts/

Kissui, B. M., Kiffner, C., König, H. J., & Montgomery, R. A. (2019). Patterns of livestock depredation and cost-effectiveness of fortified livestock enclosures in northern Tanzania. *Ecology and evolution*, *9*(19), 11420-11433.

Kudrenko, S., Ordiz, A., Barysheva, S. L., Baskin, L., and Swenson, J. E. (2020). Human injuries and fatalities caused by brown bears in Russia, 1932–2017. *Wildlife Biology*, *2020*(1).

KWS (2019). Human wildlife compensation report (2014-2017). Retrieved from http://www.kws.go.ke/content/human-wildlife-compensation-report-2014-2017-launched.

Letiva, P. (2018). New twist to human-wildlife conflict. Daily Nation. Retrieved from https://www.nation.co.ke/lifestyle/dn2/New-twist-to-human-wildlife-conflict/957860-4303878-vqnv49/index.html on 11th May 2020. Is it cited?

Macharia, P. M., Giorgi, E., Thuranira, P. N., Joseph, N. K., Sartorius, B., Snow, R. W., & Okiro, E. A. (2019). Sub national variation and inequalities in under-five mortality in Kenya since 1965. *BMC public health, 19*(1), 146. Is it cited?

Manoa, D. O., Mwaura, F., Thuita, T., and Mukhovi, S. (2020). A review of the Visible and Hidden Opportunity Costs of Human-Wildlife Conflict in Kenya. *Journal of Biodiversity Management and Forestry*, 9:2.

Manoa, D.O. and Mwaura, F. (2016) Predator-Proof Bomas as a Tool in Mitigating Human-Predator Conflict in Loitokitok Sub-County, Amboseli Region of Kenya. *Natural Resources*, **7**, 28-39. http://dx.doi.org/10.4236/nr.2016.71003

Mariki, S. B., Svarstad, H., and Benjaminsen, T. A. (2015). Elephants over the cliff: explaining wildlife killings in Tanzania. Land Use Policy 44, 19–30. doi: 10.1016/j.landusepol.2014.10.018

Mayberry, A. L., Hovorka, A. J., & Evans, K. E. (2017). Well-being impacts of human-elephant conflict in Khumaga, Botswana: exploring visible and hidden dimensions. *Conservation and Society*, *15*(3), 280-291.

Messmer, T. (2019). The growing business of human–wildlife conflict management. Human–Wildlife Interactions 13(1):1–2. DOI: https://doi.org/10.26076/a969-w636

Mg hoi, C. (2018). KWS makes Sh 35m payout for deadly attacks. People Daily Newspaper, P.24.

Mukeka, J. M., Ogutu, J. O., Kanga, E., & Røskaft, E. (2019). Trends in compensation for human-wildlife conflict losses in Kenya. *International Journal of Biodiversity and Conservation*, 11(3): 90-113.

Mukeka, J. M., Ogutu, J. O., Kanga, E., and Roskaft, E. (2018). Characteristics of human-wildlife conflicts in Kenya: Examples of Tsavo and Maamai Mara Regions. *Environment and Natural Resources Research*, *8*(3), 148. Is it cited?

Muriuki, M.W., Ipara, H. and Kiringe, J.W (2017). The cost of livestock lost to lions and other wildlife species in the Amboseli ecosystem, Kenya. *European Journal of Wildlife Research*, 63**:**60 https://doi.org/10.1007/s10344-017-1117-2

Naha D, Sathyakumar S, Dash S, Chettri A, Rawat GS (2019). Assessment and prediction of spatial patterns of human-elephant conflicts in changing land cover scenarios of a human dominated landscape in North Bengal. PLoS ONE 14(2)

Naughton, L., Rose, R., & Treves, A. (1999). The social dimensions of human-elephant conflict in Africa: a literature review and case studies from Uganda and Cameroon. A Report to the African Elephant Specialist Group, Human-Elephant Conflict Task Force, IUCN, Glands, Switzerland.

Ngene, S., Okello, M. M., Mukai, J., Moya, S., Njumbi, S., & Isiche, J. (2017). Home range sizes and space use of African elephants (*Loxodonta africana*) in the Southern Kenya and Northern Tanzania borderland landscape. *International Journal of Biodiversity and Conservation*, *9*(1): 9-26

Ngene, S.M and Omondi, P. (2008). The costs of living with elephants in the areas adjacent to Marsabit National Park and reserve. Pachyderm, 45 July 2008–June 2009.

Nyhus, P. J. (2016). Human–Wildlife Conflict and Coexistence. Annual Review of Environment and Resources, 41, 143–7.

Ogada, M.O., Woodroffe, R., Oguge, N. and Frank, L. (2003). Limiting Depredation by African Carnivores: the Role of Livestock Husbandry. Conservation Biology 17(6), 1521–1530.

Ogra, M. (2008). Human-wildlife conflict and gender in protected area borderlands: A case study of costs, perceptions, and vulnerabilities from Uttarakhand (Uttaranchal), India. Geoforum, 39, 1408-1422.

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

Okello, M. M., Kiringe, J. W., & Warinwa, F. (2014a). Human-Carnivore Conflicts in Private Conservancy Lands of Elerai and Oltiyiani in Amboseli Area, Kenya. *Natural Resources*, *2014*.

Okello, M. M., Njumbi, S. J., Kiringe, J. W., & Isiiche, J. (2014b). Prevalence and severity of current human-elephant conflicts in Amboseli Ecosystem, Kenya: insights from the Field and Key Informants. *Natural Resources*, *2014*.

WWF (2020). Battles over ever decreasing land. World Wide Fund for Nature. Retrieved from: https://wwf.panda.org/knowledge_hub/endangered_species/elephants/human_elephant_conflict.cfm.

Zakayo, F. (2014). Human-crocodile conflicts in areas adjacent to Lake Rukwa and Momba River, Momba District, Tanzania. Masters Dissertation, Sokoine University of Agriculture.

Patterson, B.D., Kasiki, S.M., Selempo, E. & Kays, R.W. (2004). Livestock predation by lions (Panthera leo) and other carnivores on ranches neighbouring Tsavo national parks, Kenya. *Biological Conservation*, 119:507-516.

Robertson, J. A. D., Roodbol, M., Bowles, M. D., Dures, S. G., and Rowcliffe, J. M. (2019). Environmental predictors of livestock predation: a lion's tale. *Oryx*, 1-10.

Shaffer, L. J., Khadka K. K. , Van Den Hoek, J. & Naithani, K. J. (2019). Human-Elephant Conflict: A Review of Current Management Strategies and Future Directions. *Front. Ecol. Evol., 6: 235. Doi:10.3389/fevo.2018.00235.*

Sitati, N. W. (2003). Human-elephant conflicts in the Masai Mara dispersal areas of Transmara District. (Ph. D. thesis). University of Kent. Is it cited?

Sitienei, A. J., Jiwen, G., and Ngene, S. M. (2014). Assessing the cost of living with elephants (*Loxodonta africana*) in areas adjacent to Meru National Park, Kenya. *European journal of wildlife research,* 60(2): 323-330. Is it cited?

Syombua, M.J. (2013). An Analysis of Human-Wildlife Conflicts in Tsavo West – Amboseli Agro-Ecosystem using an Integrated Geospatial Approach: A Case Study of Taveta District (PhD Thesis), University of Nairobi.

Taruvinga, A., & Mushunje, A. (2014). Society's Perceptions of African Elephants and their Relative Influence towards the Conservation of Elephants. *APCBEE procedia*, *10*, 299-304.

USDA (2012). Maryland Farmers Estimate $10.0 Million in 2011 Wildlife Related Crop Losses [Press release]. Retrieved from https://www.nass.usda.gov/Statistics_by_State/Maryland/Publications/Wildlife_Damage/mpr04-12Wildlife.pdf