Exploring Human-Elephant Coexistence: *Testing a Conflict Mitigation Tool for Elephant in Enduimet Wildlife Management Area, West Kilimanjaro*

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Executive Summary

As human-elephant conflict (HEC) increases, a better understanding of the human dimensions of these conflicts and non-violent mitigation methods are needed to foster long-term coexistence. In this study, we conducted household questionnaires (n = 296) to assess the prevalence of HEC and attitudes towards elephants in ten villages in EWMA. In addition, we evaluated the effectiveness of beehive fencing as a deterrent against elephant crop raiding for sustainable solution for HEC. The majority of the households reported seeing elephants near their property at least 2-3 times a week N=259(25.2%) and experienced negative impacts from elephants in the last 4 years, (2022-2024). The beehive fence deterred 83.4% of individual elephants (n = 121) and 74.3% of elephant groups (n = 28) that approached the fence. Most elephants (62.01%) exhibited behaviors suggesting heightened attentiveness. The farmers reported economic and social benefits of the beehive fence. By contributing to farmer income and reducing crop damage caused by wild elephants, beehive fencing may provide an important locally managed complement to national HEC mitigation methods. However, we recommend more studies with a larger sample size of farms and including controls in the study design.

Acknowledgments

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1.0 INTRODUCTION

The expansion of human settlements and agriculture near protected areas (PAs) has led to habitat loss, reduced forage, fragmented landscapes and a decline in wildlife populations. As habitats shrink, wildlife increasingly come into contact with humans, causing conflicts over space and resources, such as crop raiding and loss of life. This conflict is termed as human-wildlife conflicts (HWCs) and it may further occur when wildlife damage crops, infrastructure, and property, or attack people, causing injuries or deaths. This can lead to retaliatory behavior where humans kill wildlife as a revenge thus endangering wildlife species.

Elephants have been highly involved in conflicts with humans by causing crops raiding, which heightens negative attitudes towards wildlife conservation and results to human-elephant conflicts (HECs). HECs are particularly severe, impacting human socio-economic and cultural lives and threatening elephant survival. In Indonesia and China, elephants have caused significant damage (Nyhus and Tilson, 2004; Chen et al. 2016), and similar issues are seen in African countries such as Cameroon, Zimbabwe and Namibia (O'Connel-Rodwell et al. 2000; Hedges and Gunaryadi, 2010). HECs also impact elephant populations, with many elephants being killed annually to prevent human deaths. This, along with poaching and habitat degradation, has drastically reduced African elephant population over the last century (Archie and Chiyo, 2012; Estes et al. 2012).

In Tanzania, wildlife management is overseen by the Ministry of Natural Resources and Tourism. The Ministry promotes community-based natural resource management (CBNRM) through Wildlife Management Areas (WMAs) to mitigate HWCs. WMAs help enforce wildlife laws and implement various protection strategies. However, increasing human populations and climate change continue to threaten these areas, as seen in the Enduimet Wildlife Management Area (EWMA), which experiences frequent elephant crop raids. In our previous project funded by Rufford Foundation, we found that an average 185 elephant crop raiding incidents do occur annually in the EWMA. It was also found that elephant crop raiding incidences occurred mostly to farmland closer to the protected area boundaries. As an outcome, a detailed map of the HECs hotspots in areas surrounding the EWMA was produced. Additionally, the project, shown that conservation awareness is vital to foster co-existence as the communities usually develop negative attitudes towards elephants following crop raid incidences, injuries, death and damage of infrastructures caused by elephants. Following occurrences of HECs incidences in the EWMA, through focus group discussions in phase one project it was discovered that local communities have been trying to mitigate the conflicts through different traditional non-lethal strategies which include noise making, use of fire, use of torches, burning of chill bricks, chill burning, farm guarding, use of dogs to scare elephant just to mention a few. Unfortunately, almost all strategies have failed to achieve the goal as they lose their effectiveness with time. Nevertheless, mitigation strategies such as trenches, electrical fences and light flashes are crucial but often expensive and raise animal welfare concerns. Thus, there was a need to find another HEC mitigation strategy which can yield positive results. Beehive fencing has been demonstrated to be one of the effective HECs mitigation strategy through reducing crop raids by elephants. While beehive fences can play the crucial role of minimizing HECs and improving community livelihoods by increasing crop productivity and honey harvesting, its effectiveness remains untested in Tanzania. Therefore, this project aimed to: (i) assess the effectiveness of beehive fencing as a deterrent against elephant crop raiding; (ii)

assess farmers perceptions of beehive fencing and coexistence with elephants; (iii) raise awareness about elephant conservation among communities residing in or near elephant habitats; and (iv) review the potential approaches used for HEC mitigation in Enduimet Wildlife Management Area.

2.0 MATERIALS AND METHODS

2.1 Study area

The study project was conducted in 10 villages surrounding EWMA, a wilderness covering 752 km² in the Longido District of the Arusha Region. The EWMA bordered the Kilimanjaro National Park to the southeast, the Tanzania-Kenya political boundary to the north and the Ngasurai plains to the west. The EWMA connects the Kilimanjaro andAmboseli ecosystems, serving as a crucial wet-season dispersal and feeding area for wildlife from Amboseli and Kilimanjaro National Parks.
Established in 2003 under the Tanzania Wildlife Policy of 1998, the EWMA consists of 10 villages mainly along the productive slopes of Mt. Kilimanjaro. It provides a vital wet-season sanctuary for elephants and other species. The most common wildlife in the area includes wildebeest, zebra, gazelles, impalas, giraffes and baboons. Depending on the time of year, elephants and zebras are a very common sight given the region lies along an elephant Kitendeni Wildlife Corridor (KWC) linking Kenya's Amboselis, Arusha National Park & Mt. Kilimanjaro in Tanzania. The area receives annual rainfall between 300mm and 600mm, with daily temperatures ranging from 30°C to 35°C and elevations between 1,230m and 1,600m. The long rainy season lasts from March to May, and the short rainy season from August to October, during which agro-pastoralists grow crops like maize and beans.
EWMA's vegetation consists mainly of woodlands, *Vachellia commiphora* brushland, *Vachellia tortilis* savannah and Sporobolus short grass plains, typical of semi-arid East African savannah. EWMA contains fertile lands with high agricultural potential and several human settlements, particularly in the villages of Tingatinga, Elerai, Lerang'wa, Kamwanga, Irkaswa, and Olmolog, where human activity has intensified. The EWMA is threatened by expanding human activities and changes in land use. The human population in EWMA is about 57,103, having increased by 30% between 1988 and 2022. Traditionally, the resident Maasai were nomadic pastoralists, but agriculture and tourism-related activities have become significant income sources.

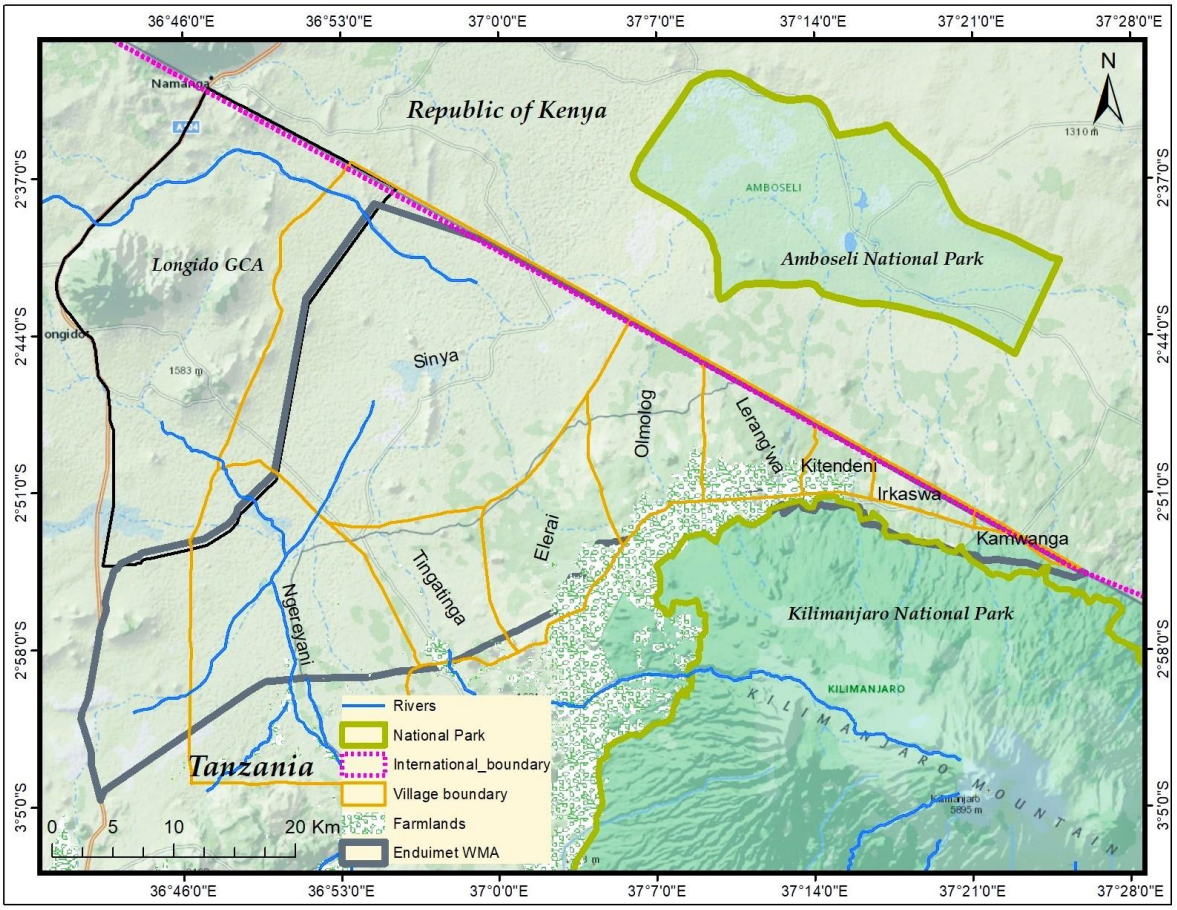

Figure 1: *Map of the study area showing the location of Enduimet Wildlife Management area*

Figure 2: Vegetation cover savannah in the Enduimet Wildlife Management Area.

2.2 Data collection

In order to address the objectives intended for this study, we employed the following approaches.

2.2.1 Installation of beehive fences

In July 2024, we adopted design for ongoing beehive fence study in EWMA. The farms were located at about 5 km distance from the EWMA boundary. A beehive fence with a length of 5 km and with 50 hives constructed in April 2024, using a beehive fence construction manual developed in Kenya by Lucy King, 2019 (Figure 3). Kenyan top-bar beehives were hung 10m apart on strong fencing wire between wooden poles and were subsequently colonized by wild bees. The individual hives were connected with wire, so an elephant trying to pass between them would cause them to swing and provoke bees to fly out in defence. Each hive had a roof to protect it from rain and sun. The fence was erected in Tingatinga, near the elephants' preferred routes into farms and where elephant visits occurred most frequently (Kabepele et al. 2011). The elephant crossings of the fence were monitored 6 days per week from April 2024 onwards, whereby data on the location of fence crossings and whether these occurred between occupied or unoccupied hives were collected. To observe elephant reactions to the beehive fence, 12 motion sensor-triggered Bushnell Trophy Cam HD camera traps were installed on trees near the fence at 1.5 m above the ground. The camera traps were programmed to take a photo after one minute. The camera continued for 4 months, from April 1, 2024 to August 31, 2024

Figure 3: *Design of the bee hives placements in the Enduimet Wildlife management area.*

2.2.2 *Literature review*

Different reports, books and journals on HECs management techniques and mitigation measures both printed and electronic materials were reviewed to get enough insights on the subject matter before commencement of the field activities.

2.2.3 Household questionnaires

In April 2024, we surveyed 1027 households in 11 villages surrounding EWMA including Tingatinga (*n*=93), Elerai (*n* = 93), Lerang'wa (*n* = 93), Kamwanga (*n* = 93), Irkaswa (*n* = 97), Olmolog (*n* = 93), Ildonyo (*n* = 93), Eldonyomali (*n* = 93), Ngereyani (n=93), Leremeta (n=93) and Kitendeni (*n* = 93), representing 0.02.8.8% of the total number of households. The current population of EWMA is approximately 37,000, having increased by 30% from 1988 to 2022 (NBS, 2022). The questionnaire (Appendix 1) used in this study was adopted from a previous study we conducted in EWMA (Sanare *et al.* 2020). However, before deploying the questionnaire to the local community, we discussed the content of the questionnaire with representatives from the EWMA. After discussion, the questionnaire was aligned to the six main questions: (a) How often do you see or hear elephants near your property? (b) Over the last 2 years, did you or any of your family members experience a negative impact from elephants? (e.g., crop damage, property damage, human injuries or death, fear, lack of sleep, or stress); (c) Is the population of elephant increased in EWMA over the past two years? (d) What are your feelings towards coexistence with elephant? and (e) Have you ever tried any methods to deter the elephants (f) what time of the day elephant crops mostly on farms?

The village leaders facilitated the distribution of the printed questionnaires to households which were evenly distributed through the HECs hotshots' areas. All household members above 18 years old that were present during the survey were eligible to participate. The participation was voluntary, and consent was obtained from the respondent before filling the questionnaire.

2.2.4 Training

We conducted educational training on the HEC issues and raised awareness about elephant conservation. This was done by distributing several educational resource materials including banners, posters, stickers, placards, booklets, and education kits. The education materials were both in print and electronic focusing on the elephant conservation, ecology, behaviour, HECs mitigation and importance for the EWMA landscape in general. Additionally, we used five days to conduct conservation education and HECs mitigation awareness programs.

2.3 Data analysis

Household questionnaire data were analysed using descriptive statistics. For the beehive fence study, we used statistical tool to assess how elephant group size, the proportion of males and female per group. The number of elephants, sex of the group (all male or not), and percentage observed in each photo was determined. All statistical analyses were performed using SPSS Statistics version 25 and alpha was set at .05.

2.4 Ethics consideration

This study was approved the Tanzania Wildlife Research Institute (TAWIRI) and Tanzania Commission for Science and Technology (COSTECH) under permit number 2020-148-NA-2020-05. Access to the study area was approved by Longido District Executive Director Districts, Enduimet Wildlife Management Area (EWMA), and Village Executive Officers (VEOs) of Kitendeni, Tingatinga, Elerai, Irkaswa and Sinya. A consent was obtained from all individuals who participated in this study and the information provided was treated as confidential.

3.0 RESULTS

3.3 Assess the effectiveness of beehive fencing as a deterrent against elephant crop raiding.

In total, we observed 121 elephants in 708 photos taken during the four months of observation with an average of two elephants per photo (Table 1). The majority (59.2%) of the observed elephants were female while 40.8% were males. Generally, five events with a group of more than 12 elephants were recorded. Of those five events with more than 12 individuals, only one group crossed the fence. Furthermore, two-thirds of the fence breaking tries had less than four elephants. Sex of the elephant groups was approximately equally distributed, with 32.7% of the groups approaching the fence were comprised of all-males, 35.7% mixed-sex groups, and 18.6% all-female. Mixed-sex groups frequently crossed the fence (49.0%) as compared to the single sex (male/female) groups. We also found that installed beehive fence deterred 74.3% of the elephant groups (*n* = 28) and 83.4% of the individual elephants (*N* = 121) that approached the fence. In the majority of the elephants who attempted to cross the fence (62.01%) exhibited some type of attentive or alarm behavior (Table 1). The most commonly observed behaviors were touching or reaching out to the fence and slowly retreating or fleeing. The elephant crop foraging frequency declined over the course of the study. The probabilities of crop foraging in the absence of the beehive fence and when it was installed, were 0.23 and 0.11 respectively.

Table 1; Descriptive statistics of 708 taken photos showing a total of (*N*=121) elephants approaching the beehive fence in EWMA

Total number of elephants	***N (%)***
Observed	121
Cross the fence	12
Mean elephant group size (*x*)	2
Sex of elephant recorded (*N*=121)	
Male	50 (40.8)
Female	71 (59.2)
Elephants group per event (n = 25)	
All-male elephant groups	13 (32.7)
% of all male elephant groups crossed the fence	3 (30.0)
Mixed-sex elephant group	12 (35.7)
% of mixed -sex elephant groups crossed the fence	5 (49.0)
All females	11 (18.6)
% of females crossed the fence	4 (25.0)
Behaviour observed by elephants near the beehive fence (*N*=129)	
Relax	31 (24.03)
Attentive	80(62.01)
Alarmed	18 (13.95)

3.1 Assess farmers perceptions of beehive fencing and coexistence with elephants

We obtained a total of 1027 respondents from household questionnaire survey with 51.5% of the respondents being females. The most represented age group was 40-50 years old (27.7% of respondents), while the least represented was 51-60 years old (2.5%). On the other hand, 259 (25.2%) respondents reported seeing or hearing elephants near their property at 2-3 times a week while 217 (21.1%) encountered elephants daily (Table 2).

Table 2; Descriptive statistics, HEC experience among different age groups among household survey respondents in EWMA (n = 1027)

Gender		**Sample counts (N)**	**Percentage**
	Male	498	48.5
	Female	529	51.5
	Total	**1027**	**100.0**
Age group			
	18-28	247	24.1
	29-39	391	38.1
	40-50	284	27.7
	51-60	26	2.5
	61-70	79	7.7
	Total	**1027**	**100.0**
Frequency of seeing elephants			
	Daily	217	21.1
	Once a week	26	2.5
	2-3 times a week	259	25.2
	2-3 times a month	120	11.7
	A few times a year	220	21.4
	Once a year or less	185	18.0
	Total	**1027**	**100.0**

Most respondents indicated that HECs increased significantly from 13.9% in 2022 to 68.1% in 2024. They also reported negative impacts from elephants, including crop raids, infrastructure damage, and destruction of various water sources. When asked about their feelings towards coexistence, almost 71% of the respondents reported to be unconditional tolerant with elephant, 16.2% referred their feeling as conditionally tolerant (i.e., only if elephants would stop causing damage); and 13.2% preferred local eradication of elephants (Table 3).

The respondents mentioned that the most commonly used methods to deter elephants are the use of blow horn (38.1%), torch (24.1%), beehives (14.5%), chilli cracker (13.1%), flashflash (7.7%) and roman candle (2.5%). Additionally, asked about their future plans related to crop damage, only a minority of respondents believed they would be able to continue current farming practices, whereas about

15–40% believed better mitigation measures (e.g., changing to a different crop) would be needed.
Moreover, the HECs incidents across the 11 villages forming EWMA in shown that most of the crop raiding events (65.8%) took place during the midnight while only 0.1% took place in afternoon (Table 3).

Table 3; The status and nature of HECs and commonly methods used among household survey respondents in EWMA (n = 1047)

Trend of the last 3 years	Sample counts (N)	Percentage
2022	143	13.9
2023	185	18.0
2024	699	68.1
Total	**1027**	**100.00**
Commonly used methods to deter elephants		
Torch	247	24.1
Blow horn	391	38.1
Chilli cracker	135	13.1
Roman candle	26	2.5
Bee hives	149	14.5
Flashflash	79	7.7
Total	**1027**	**100.0**
Incident time		
Afternoon	1	0.1
Evening	4	0.4
Midnight	676	65.8
Morning	8	0.8
Night	338	32.9
Total	**1027**	**100.0**
Feelings toward coexistence with elephants		
Conditional tolerant	166	16.2
unconditional tolerant	725	70.6
Eradicate	136	13.2
Total	**1027**	**100.0**

3.2 Raise awareness about elephant conservation among communities residing in or near elephant habitats in EWMA

Staff from the EWMA were trained and required to monitor key threats to the EWMA especially those targeting elephants. In addition, 50 individuals from 10 villages forming the EWMA were trained on the importance of elephant conservation. Through an intensive 5 days lectures and practical sessions that were done in the EWMA offices, rangers increased their knowledge and skills on protection of the elephant as well as use and manipulation of field tools such as GPS, binoculars, and cameras.
About 20 posters on elephant conservation were published and distributed to the participants of massive conservation awareness session. Similarly, 30 calendars were published with the message of elephant conservation and distributed during the session. Additionally, 26 conservation education sessions were conducted among community members. The aim of conservation education sessions was to involve local community for the conservation of elephant in EWMA by minimizing HEC.

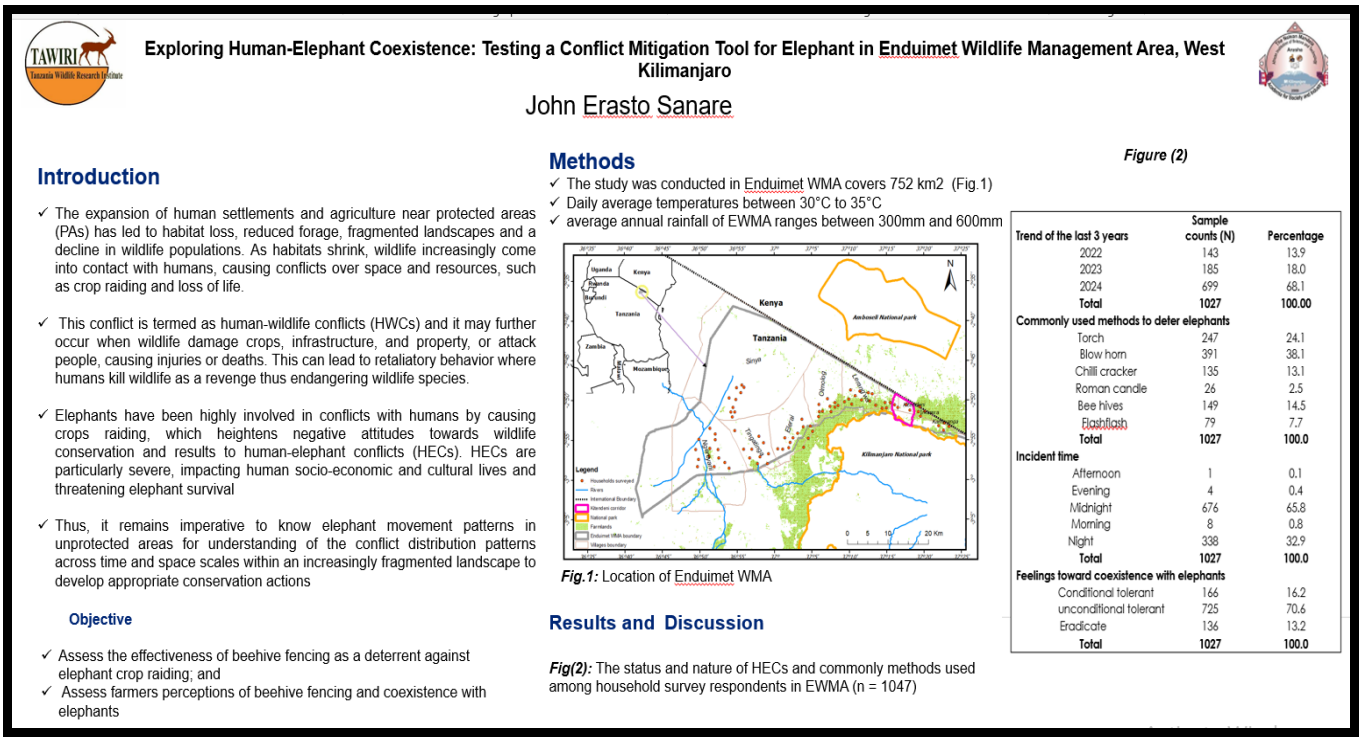

Figure 4: *Design of the poster for awareness raise in the Enduimet Wildlife Management Area.*

Figure 5: *Research team in Enduimet WMA*

3.5 Review of the potential approaches used for HEC mitigation in Enduimet Wildlife Management Area

In EWMA a multitude of traditional methods have been developed over the years to prevent crop raiding by elephants in conflict hotspots areas. The escalation of HECS in the past few years and technological advances have resulted in development of additional methods to address the problem.

Although, traditional methods are easy to use, have low costs and are more effective at low levels of conflict, more technical need to be used which carry higher costs. The techniques employed in HECs mitigation in EWMA range from chasing elephants by noise making, making fire, use of torches, burning of chill bricks, chill burning, guarding, use of dogs to scare elephant etc. Noone method is a 'standalone' universal solution for conflict mitigation as each technique has its advantages and disadvantages and are used in differing permutations to increase their effectiveness. Farming practices, traditions of people, habitat characteristics and resource availability may vary widely across the range of elephants. Thus, local information is vital to determine what methods will be appropriate for a given situation.

The Focus Group Discussion (FGDs) held in 11 villages forming EWMA; centred on the occurrence of HECs in EWMA and the mitigation approaches used, the respondents mentioned that local community have been trying to mitigate the conflict through different non-lethal methods. The tactics include noise making, use of fire, use of torches, burning of chilli bricks, chilli burning, guarding, use of dogs to scare elephant etc. Unfortunately, almost of the measures that are being used have not been successful to achieve the desired goal. For instance, elephants nowadays don't get scared by loud noises either by shouting, drum beating, vuvuzela etc. Being intelligent and highly adaptable, elephants also learn to overcome many of the methods used for mitigation, and methods that were initially successful may lose their effectiveness over time. This also applies to other tactics because elephants get used to them over time. In general, the methods have lost their effectiveness, people just choose to use whichever is available because their performance does not differ significantly.

Figure 6: *Research team in Enduimet Wildlife Management Area*

3.5 Suggestions to increase the efficiency of the wildlife authorities to mitigate HWCs

The local community suggested that the government should recruit more Game Officers and station them in the villages which are HEC hotspots. Also, the DGO office should have enough resources both human and equipment.

Expressive quotations from the focus groups.

"To effectively address human-elephant conflict (HEC), the government should consider increasing the number of District Game Officers (DGOs) and building fences around protected areas to prevent elephants from entering farmland. Establishing HEC response centers in hotspot areas would also be beneficial, given the growing elephant population. Additionally, the government should consider culling some elephants in village areas to reduce population pressure. When other elephants witness this, they may avoid returning to these areas, which could give villagers relief from HEC for an extended period."

4.0 DISCUSSION

The first objective of this study is to evaluate the prevalence of HEC and attitudes towards elephants in 11 villages in EWMA. Findings from household survey questionnaire confirm that HEC is widespread and increasing in EWMA similar results to (Amjad, 2019). The majority of households in the EWMA stated they encounter elephants weekly and directly experience negative impacts from elephants, including damage to crops and property. Only a small proportion of villagers stated that they would continue current farming practices if HEC would persist, suggesting that the majority would be forced to either discontinue or change their practices. Yet, despite the scale and severity of HEC, most villagers stated they do not support local eradication of elephants but prefer conditional tolerance. In addition to the widespread impact of HEC, our findings demonstrate that the majority of villagers do gain benefits from living near elephants. Potentially as a consequence of this, most of them do agree and feel it is important to invest in conservation particularly in savannah elephant. This idea is in line with qualitative findings from our farmers interviews, which highlight the importance of socio-economic benefits in realizing peaceful coexistence with elephants. Taken together, our results highlight a need for sustainable, integrated solutions that not only reduce damage by elephants but also increase their value for local people (Minwary, 2009).

The second objective is to assess the effectiveness of beehive fencing as a deterrent against elephant crop raiding in EWMA. The *beehive* fence deterred 74.3% of the elephant groups and 83.4% of the individual elephants. Results reveal attentive and alarm responses of elephants at the fence, providing evidence of specific behavioral reactions to the presence of bees. In addition, the farmers reported a significant reduction in crop damage after the fence was installed. These results suggest that beehive fences can be a sustainable local method to reduce crop damage by elephants and to generate supplemental income for farmers in EWMA. Implementation of beehive fences might be prioritized on smaller farms that are most proximal to significant elephant populations or located along commonly utilized elephant corridors.

In addition to evaluating the effectiveness of the beehive fence, our results indicated no effect of elephant group size, all-male groups on the likelihood of elephants crossing the fence. This contrasts with studies that found crop damage to be more prevalent in relatively smaller groups (King et al., Kioko et al., 2017) and all-

male or male-dominated groups (Sinha, 2010). Interestingly, compared to similar studies (e.g., King et al.,2018), we observed female groups near the beehive fence. Female herds of elephants may avoid damaging crops due to the presence of calves or other more vulnerable individuals. Our study showed that about two-thirds of the fence-breaking attempt events had three elephants or less, which is in concordance with findings from Kenya (i.e., 73%; King et al.,). Compared to other studies, we observed a more equal distribution of all-male elephant groups, mixed-sex groups and solo females. In contrast, the majority of the elephants approaching the beehive fence in Kenya were males (King et al.,) and all of the elephants feeding on crops in a study in Tanzania were males (Smit, Pozo, Cusack, Nowak, & Jones,). This may be because large breeding herds are permanently living outside PAs.

5.0 RECOMMENDATIONS

This study provides insights into the potential of beehive fences to mitigate HEC in EWMA in order to confirm these preliminary results, we recommend that future studies should consider a larger sample size of farms and include controls in the study design. Generally, our results indicate that beehive fencing can be a useful tool to mitigate HEC and create more positive perceptions of elephants and conservation. Although the method is labour-intensive and relatively expensive, beehive fences have a positive effect on the livelihoods of households, in terms of reducing crop damage, generating alternative income, and skill development. Combined with other community-based conservation projects, beehive fences can help elephants and people to coexist in other HEC areas.

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Appendix 1: Questionnaire for local respondents

A. PERSONAL INFORMATION

1. Age

- 25-35 ( )
- 36-46 ( )
- 47-57 ( )
- above 57

2. Sex:

- Male ( )
- Female ( )

3. Are you a resident of this village?

- Yes ( )
- No ( )

4. If yes, how long have lived in this village

- 1-5 ( )
- 6-10 ( )
- 11-15 ( )
- iv) Above 15

B. HUMAN-ELEPHANTS CONFLICTS

1. Have you ever encountered with elephants in your area or village?

- Yes ( )
- No ( )

2. How often do they visit?

- Daily Once a week ( )
- Twice a week ( )
- Any time ( )

3. Which time of the day?

- Day time ( )
- At night ( )
- Any time ( )

4. What season of the year?

- Wet ( )
- Dry ( )

5. What is your opinion on the presence or absence of game officers at your village? ……

C. MITIGATIONS MEASURES

1. What are your suggestions to control or mitigate Elephant impacts in your village areas? ……
2. Do you chase or repel elephant approaching your house or farm land?
    - Yes ( )
    - No ( )
3. If yes which method are frequently used.
    - Torch & Horn
    - Torch, Horn and Chili-crackers
    - Torch, horn, Chili and Flashflash
    - Other (explain)

5 Could you suggest how this problem of human- Elephant can be solve