International Elephant Foundation Final Report 2019

Elephant deterrents, behavioral responses, and ecological correlates of crop-raiding

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2. Conservation Needs of Project in 2019

The Kasigau Corridor REDD+ (Reduce Emissions from Deforestation and forest Degradation) Project Area includes 14 Group Ranches covering an area of ca. 2000 km^2 that is part of the Kasigau Wildlife Corridor between Tsavo East and Tsavo West NP (Figure 1). These ranches are conserved under a REDD++ scheme that aims to provide financial incentives by tapping into the carbon market to help protect forests. Wildlife Works has pioneered practical REDD++ solutions that are acceptable to both the rural communities and the marketplace. The biological component of the study involves elephant surveys and monitoring and are mainly undertaken within Rukinga Wildlife Sanctuary (30,000 ha).

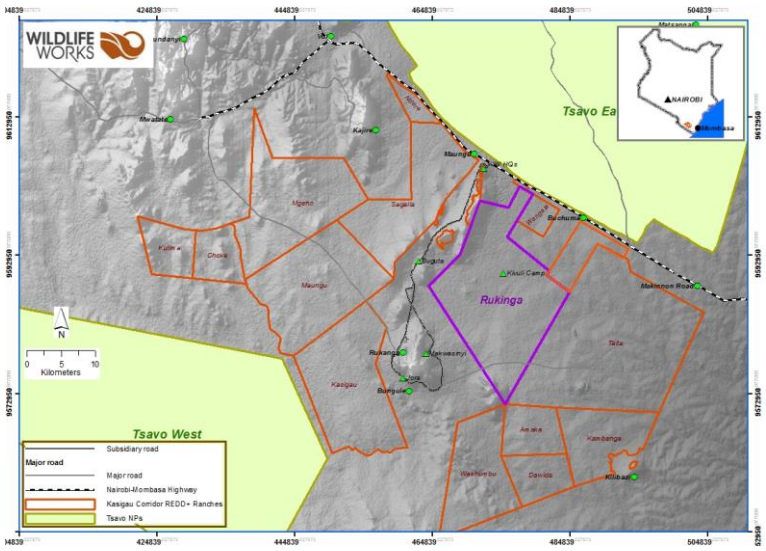

Figure 1. Map of project site location showing Rukinga Ranch and the remainder of the Kasigau Corridor ranches in the REDD+ Project. (NB: Kivuli Camp is the project's main base.)

Kenyan elephant populations started to rebound from the poaching crisis of the 1970's and 80's. As elephants attempted to expand into their historical areas, human encroachment and agricultural development had compressed and fragmented these ranges. Negative encounters with people result in human elephant conflict (HEC), and combined with poaching and range loss, HEC is contributing the downward trend of elephant populations in many areas. The major issues related to HEC represent the primary conservation objectives of this project:

(1) Crop raiding is the major form of HEC, and crop losses from elephants can severely influence livelihoods. Therefore, there is a need to identify sustainable and affordable means to reduce crop raiding by elephants. Rukinga Ranch has no permanent residents, but community owned ranches and villages surround it; thus, negative encounters with wildlife at the boundaries of this area of refuge are common. Farmers would benefit from means of deterring elephants that approach their crops and being warned of elephants from a distance heading in the direction of their fields. We are continuing to focus on experimental examination of deterrents and ecological indicators of potential crop raiding, and are testing additional deterrent types. In 2019, we explored aspects of early warning system(s) to alert farmers of impending elephant presence near their farms, and investigated other biotic factors that may be underreported as causes of crop mortality. People's poor attitudes towards elephants reduce the effectiveness of conservation initiatives and practices, ultimately resulting in a decline in elephant populations. People often attribute crop raiding to any elephants in the area, but it

is possible only particular individuals are the culprits and other species may also be to blame. Many adult elephants (especially bulls) that we catalogued in the project area have one or more large scars, some of which may be the result of negative encounters with the local people. By determining which elephants and what other species crop raid, we can target solutions and enhance human attitudes towards elephants in general. Crop raiding by elephants needs to be considered in perspective of overall crop yield. Previous studies have shown that farmers will attribute crop losses to elephants even when elephants are not the primary reason for crop mortality. To improve human livelihoods, we need to know the relative importance of various factors on crop survival and have data on the prevalence of elephant crop raiding. We are evaluating the role of elands as crop raiders, a species that can cause extensive crop damage but whose role in crop losses appears underreported.

(2) Elephant presence in confined areas or recovering ecosystems, such as the wildlife corridor at our study site, can result in extensive damage to canopy trees and influence the presence of other mammals and birds. Bark striping that results in girdling a tree or pushing over large trees can lead to mortality. These trees provide habitat (e.g., nesting sites) and cover for other species. In addition, humans use these trees as a resource for lumber, medicinal products, food, and fuel. The project site was formally a cattle ranch and faunal diversity is still recovering from years of overgrazing. Thus, there is a need to maintain these trees in the habitat for elephants, wildlife, and humans (although cutting of trees is not permitted). Furthermore, we are determining how the timing and extent of damage to trees by elephants relates to the probability of crop raiding. Elephant activities can facilitate biodiversity and enhance ecosystem services. However, elephants confined by human presence or enclosed by fences can overuse a particular habitat resulting in a loss of biodiversity. Elephants and their activities can facilitate enhanced biodiversity but not all species are favored by elephant presence. Thus, highly mobile yet easy to locate species such as larger mammals and predatory birds may be indicators of elephant absence or presence and potentially signal temporal shifts in crop raiding rates as well as elucidating the broader influence of elephants on local biodiversity. Through wildlife surveys we can assess the overall biodiversity of the ranch while evaluating potential indicator species.

3. Goals and Objectives of Project in 2019

(1) HEC

a. *Deterrent Fences*. We are testing **deterrent fences to reduce elephant intrusion** into crop fields. The fifth (T5) trial was conducted in mid-2019, and the sixth trial (T6) is nearing completion. We continue to test the single-stranded Kasaine fence for effectiveness. In addition, we are tested a new double-stranded Kasaine fence. Wildlife Works has deployed a front-line single Kasaine fence in the community of Ngambenyi, identified as an area of high crop raiding. Monitoring this fence can illustrate whether simpler non-encircling Kasaine fences can benefit communities. We finished construction of four blocks of beehive fences in trial four (T4) and are completing the third trial for this method (i.e., trials 4, 5, and 6 of the overall study). In 2020, we will be exploring the potential of one or more new elephant deterrents as part of the MSc thesis of Ms. Sophia Corde. A recent study by Osipova et al. (2018, *J. Applied Ecology*, 55:2673-2684) suggests that

fences can shift problems rather than solve them, so we need to be aware and concerned about **the larger landscape ramifications of deterrent fences (see Von Hagen PhD work)**.

b. *Early Warning*. We have conducted preliminary testing on Rukinga Ranch of an early warning device's ability to **reliably distinguish elephants from other animals** that are approaching farms. We are working with a Kenyan technology initiative, Sote Hub, from the nearby communities of Kajire and Voi, as well as a teacher and his students.

c. *Elephant Database*. We are determining **to what extent crop raiding occurs in our area by the same or different elephants** by establishing an identification database.

d. *Community Outreach*. A **community outreach program will be a part of the PhD thesis of Lynn Von Hagen** who will disseminate the information to those who would benefit from Kasaine fences and other practical deterrent methods. We will be incorporating Climate-Smart Agricultural (CSA) practices into the outreach program. We should see a direct benefit to elephants by reducing conflict with local farmers while collecting data that will inform us about deterrent methods that are worth trying on a broader geographic scale.

e. *School Visits*. We are making **visits to the local primary school** to facilitate a good relationship with the local community and assist with educational information on elephants and conservation. We have established a fund to help feed school children and provide school supplies to assist in improving the relationship between the local community and scientists/conservation managers.

f. *Track Crop Damage*. Beyond measuring the damage to our experimental plots from all causes (elephants, other wildlife including eland, domestic animals, insects, and lack of water), we also are **tracking incidents of elephant crop raiding in the greater farming area** to determine how commonly elephants and other wildlife are visiting the area.

(2) **Tree Damage and Mammal & Bird Diversity Surveys**

a. *Tree Damage*. We are **assessing damage caused by elephants to tree species** in the study area. As all 240 elephant-favored trees were located and tagged in the first year of the project, and rechecked in the second year. We revisited each tree again in 2019. We will use this information to assess the timing and degree of damage relative to crop raiding. We will test the hypothesis that escalating tree damage could be used as an indicator of impending crop raiding. The alternative hypothesis is that higher tree damage reflects the preference for browse over crops by elephants (especially in light of the higher costs of raiding when crops are protected). We also will use this information to determine species preferences and the relationship of damage to the permanence of the waterholes at which the trees are located. In the future, if our results suggest particular trees need protection, then we will wrap some trees of value with wire to determine if this wrapping reduces tree mortality from elephants (such mortality is primarily the result of bark stripping). Hanging beehives in trees also has been shown to be effective, but this works better in areas monitored regularly by humans (e.g., fruit trees on farms) to make sure the beehives are occupied. Such a technique could be useful when fruit trees are incorporated as a CSA alternative crop.

b. *Mammal & Bird Diversity Surveys.* We are using **surveys of mammals and higher trophic level birds** (primarily raptors) to assess biodiversity, which we have continued in this third year of the project. We are testing the hypothesis that one or more of these species could serve as indicators of elephant presence and degree of activity, such as impending crop raiding. Thus, such species could provide a biotic early warning system.

4. Specific Actions Taken to Achieve Objectives

(1) HEC

a. *Deterrent Fences***.** We have demonstrated that the new Kasaine metal strip fences singly and in combination with a chili fence have a statistically significant deterrent effect (paper in peer-review). Contrastingly, the chili fence alone was not effective. In year three (2019), we renewed the leases in each block (8 fields each) from one or more farmers, and the farmers planted maize. We erected and monitored twenty-six (28) camera traps in T5 and twenty-six (26) in T6 at the experimental fields in strategic positions near viable crops. We employed locals to assist with fence maintenance and the construction of the new and modified deterrent methods for T5. We established the configurations for T5 and T6 by adding a double Kasaine fence to replace chili fences and an additional Kasaine fence to replace the acacia fence (Table 1). Within each block, we maintained our treatments with a paired control, randomly without replacement. In addition, we have four (4) smaller blocks (2 fields each) with one beehive fence field and one dummy beehive fence control field per block. Despite having many hives occupied for T5, severe drought set in towards the end of the trial, and all bees departed. For T6, fields had some active hives in all 4 blocks. Kenya received near record rainfall in the latter half of 2019, and all farmers are expecting an abundant maize harvest.

We hosted five Earthwatch teams, collected abundant data and are still collecting data from T6 as harvest in occurring. Data were collected from T5 with analysis completed. T6 is currently ongoing and crop raiding activity will likely continue to decline after harvest, though we will continue to collect data as harvested material is “browning down”.

Table 1. Deterrent fences in late 2018 through early 2020 at the four full-size blocks (T = Trial since start of study in 2017). Number in box refers to number of times used per block (N=4 blocks). The additional beehive fence blocks are discussed in the text.

Deterrent	T4 (2018-19)	T5 (2019)	T6 (2019-20)
No fence (universal control)	1	1	1
Acacia	1	0	0
Rope control	1	0	0
Cloth flags with no chili on rope	1	0	0
Wire control	1	1	1
Kasaine (metal strips on wire)	1	2	2
Rope & Wire control	1	0	0
Cloth flags with no chili & Kasaine	1	0	0
Colored cloth & Rope & Wire control	0	1	1
Colored Cloth & Kasaine	0	1	1
Double wire control	0	1	1
Double Kasaine	0	1	1

i. **Trial Five: 5/16/19-9/2/19.** The rains for this trial arrived early and most farmers in the community planted earlier than normal. When the rain ceased, most lost everything. When the rains returned, later than normal, our blocks were planted and some community farmers had to replant. Rains were not been present in the normal pattern, so most areas did not receive enough sustainable rain to produce viable corn.

Our block 3 was completely lost to drought, though approximately 4 fields across 3 blocks made it to harvest. Despite the scarcity of mature crops, elephants were recorded as present at individual fields and within the community 165 times during this trial on most days in the trial. Commonly, elephants foraged on immature stalks, and family groups were recorded raiding several times, behavior not previously noted with our project. As most cloths and ropes from previous trials had disintegrated, we made the decision for T5 to replace the cloths on the Kasaine + chili (without oil) fences with colored cloths and new ropes and a wire and rope control. Since the cloths and ropes were no longer black from the past oil application, this created a new dynamic of a potentially more visible deterrent at a distance, and also allowed us to continue to test the hypothesis that the movement of the cloths in the wind adds deterrent power to the already successful Kasaine fence. We retained the single Kasaine fence with wire control, but replaced the chili fence and control with a second Kasaine fence with no control (maintaining the 'no fence' universal control). We additionally replaced the acacia fence with a new double Kasaine and a double wire control. All block modifications (including some pole replacements because of termite damage) were made by team members with the assistance of local labor. The beehive fences were all maintained. We reported record occupancy (33% of hives) for our study, although as the area dried our first honey actively being produced was consumed by the bees to sustain themselves. We monitored elephants more intensively as they moved through the community, tracking some individuals for up to 4 km. We continued to note regular eland presence in our experimental area and throughout the community with some farmers losing entire fields in one evening to herds of eland.

ii. **Trial Six: 11/20/19-ongoing**. The rains came early, thus farmers planted early and crops sprouted by mid-November. We maintained all elephant deterrents as in T5 and made repairs to all fences and erected and monitored cameras as before. Hive occupancy was initially high, and farmers are hoping for their first honey harvest with near record rainfalls. Many farmers are harvesting early in January/February for fear that crops will rot from ongoing rains and floods. Data input and analysis are still forthcoming for this trial.

b. *Early Warning.* In collaboration with teenagers, their teacher, and a Kenyan technology initiative, Sote Hub, from the nearby communities of Kajire and Voi, we conducted initial tests of their early warning device that would be used to alert farmers to the presence of elephants. We deployed the device on Rukinga Ranch at Salama waterhole to determine if it can differentiate between elephants and other wildlife as a form of initial testing. We erected a camera trap to correlate elephant presence with the device readings and collected over 2 months of data. We are currently awaiting information from the group so we can correlate our findings.

c. *Elephant Database*. We have created an elephant identification database, using photographs from trap cameras to identify elephants that crop raid our experimental plots, and from personal cameras of staff and volunteers when elephants are encountered throughout the ranch. Dr. Barbara McKnight started the Tsavo Elephant Research Project in 1989 and a copy of the photographs from her database is stored at the Kivuli Camp. Save the Elephants also identifies elephants in the region but not in our area. As of

February 2020, we have cataloged over 30 family groups and 135 bulls. Because of the drought in 2020, sightings were much more frequent than in previous years, especially around the permanent water sources on the ranch. Thus, we are still inputting elephants from September onward, and expect the catalogue and elephant numbers to climb even higher after analysis. We also still have camera trap sightings incoming from T6 camera traps and hope to have all crop raiding images analyzed soon. The total number of elephant sightings over the length of the project is at 3,600+ (the number of sightings in 2019 alone may exceed the entire projects' number thus far).

d. *Community Outreach*. As part of the larger project, Wildlife Works conducts surveys with people in villages in the study area to examine their attitudes on wildlife, elephant conservation, and sustainable practices to maintain a viable livelihood. Ms. Lynn Von Hagen conducted surveys at the end of 2019 of individuals from 6 different villages that will likely be involved in the workshop program. The head chiefs and sub-chiefs from the areas took Lynn to meet farmers from each area and they explained how HEC had impacted their farms and communities. They discussed potential solutions with Lynn and stated their willingness to be a part of the workshop program.

e. *School Visits.* All Earthwatch volunteer teams that assist with our project visit Sasenyi Primary School, the main school near our experimental area. These individuals help to spread the conservation message around the globe when they return home and are responsible for the initiation of our Sasenyi School Fund, which is facilitated through IEF. These volunteers have donated enough money to feed lunch to over 700 students in 2019 through March 2020. The school often runs out of water during the drought season, as water douser trucks cannot make it up the badly eroded road, and so the storage tanks at the school dry up. Donations by the volunteers facilitated the connection of the school's storage tanks to the municipal water system. Now the school will have water year-round. This outreach has made a lasting and positive impression of our project on the people of Sasenyi.

f. *Track Crop Damage*. In 2019, we added an experimental front-line fence at Ngambenyi and began collecting more data on crop damage at farms in this community in addition to our experimental area. The two Wildlife Works employees who are dedicated fence attendants continue to record daily information on crop raiding in the area. We deployed twenty-eight (28) camera traps in T5 and twenty-six (26) camera traps for T6 at strategic locations across the front line of farms. Cameras were checked weekly for wildlife crop raiding. Over T5, we documented elephant family groups actively raiding for the first time in our study; crop raiding is often attributed to male elephants, so this is an uncommon occurrence in crop raiding studies. Each crop raiding incident is being recorded in an elephant database and additional records were kept of crop raids elsewhere in the community. We have also initiated extensive tracking for crop raiding events and have followed elephants for up to 4 km as they embark on raids throughout the community. Our previous trials implicated elands as potentially important crop raiders, finding eland in one trial present as often as elephants. This past year, we saw this trend increase as we tracked wildlife presence in other areas of the communities.

Our soil sampling from 2018 by Dr. Urbanus Mutwiwa revealed poor soil nutrients, which can reduce overall crop success. As part of a renewed focus on the drivers of human

elephant conflict, the team constructed a test plot with climate smart agricultural (CSA) practices using micro water catchments, zai pits (an agricultural technique that involves digging down to the topsoil and adding manure to improve soil quality), and drought and/or elephant resistance crops accompanied by a control plot. We have conducted CSA plots over two trials with clear results of the success of treated plots versus controls. We plan to expand these plots throughout 2020, including areas where we had volunteers plant trees.

(2) Tree Damage and Mammal & Bird Surveys

a. *Tree Damage.* By November 2019, we successfully re-evaluated damage to the 240 trees spread over six transects that were originally identified in 2017. All volunteer teams assisted with the tree surveys. The rechecks of each tree were to assess how elephant damage (bark stripping, branch breaking, felling) has changed in the last year. We continued to see increases in damage in 2019 and lost several trees at one waterhole for the first time. We believe this demonstrates the selected trees were appropriate choices and that this long-term data set will be useful in determining if elephant foraging is an indicator of changes in crop raiding patterns as well as assessing the overall impact of elephants on trees in the study site.

b. *Mammal and Bird Surveys.* We continued to perform surveys along six driving transects over roads that cover the majority of the Rukinga Ranch. Each of the Earthwatch teams and scientific personnel performed transects into mid-December. Over 65 transects were performed since February of 2019, bringing our 3-year count of individuals to 9610 representing over 89 species. We are starting to analyze these data for trends that correlate with elephant activity and crop raiding.

5. Modifications of Actions

The largest modification to T5 and T6 was the change in fences to be tested by replacing acacia fences with additional single Kasaine fences, and adding double Kasaine fences in place of chili fences. A second study area in nearby Ngambenyi had the addition of a front-line Kasaine fence donated by Wildlife works, which is being monitored by the project personnel. In addition, we initiated CSA test plots and performed initial testing of an early warning system device.

Because of logistical constraints and safety issues (elephants in the bush) we scaled back the checking of trees to use the information more for an indicator of elephant pressure on the habitat over time rather than a shorter-term ecological indicator. We will focus on the mammal and bird surveys for this latter purpose. Because we now have adequate baseline species data from driving transects, we will be dropping transects in months where no crops (and therefore no crop raiding) are present.

6. Conservation Outcomes to Date

(1) HEC

a. *Deterrent Fences*. Statistical analyses from the first two trials showed that the chili + Kasaine fence and the stand-alone Kasaine fence had a significant deterrent effect. *This is exciting news for the conservation of elephants as new, practical, and effective deterrents are rare.* Based on our results, we have submitted a manuscript, which is currently in peer-review at the *African Journal of Ecology*. From our last two trials (T5 and T6), a double Kasaine fence may be even more effective; we also are seeing positive results from the front-line Kasaine fence at Ngambenyi.

Additional data obtained from the crop raiding study has provided valuable conservation information. Analysis revealed that all deterrent methods were approached equally across the four experimental blocks in the first two trials. This validates the experimental design, which could be adapted by other scientists to test a variety of deterrent methods in other locations and provides us a means to switch out deterrents for testing. We found that chili fences did not perform well in this area, and preliminary results suggest that beehive fences have performed well even when not occupied by active bee colonies. We have noted a significant eland presence in Sasenyi despite a paucity of literature suggesting they are substantial crop raiders. In our latest trials we have recorded crop raiding by elephant family groups (an unusual occurrence), and elephants were observed raiding before corn cobs emerged. We are also seeing that elephants in our area may be prone to return even when crops are "browning down".

We have taken the first steps towards planning workshop outreach programs for local villages to demonstrate the different types of effective deterrents that are available and how to construct and maintain them. The workshops will include initiatives that hope will improve opinions on conservation and address some of the root causes of HEC, such as poverty, crop failure, and lack of alternative livelihoods.

b. Early Warning. We have noted that crop raiding rates tend to rise in conjunction with elephant density on the ranch. Data from Wildlife Works aerial patrols, which keeps track of the relative abundance of elephants in the surrounding areas, may also reveal that elephant density is related to crop raiding frequency. Further research into this potential correlation provides an opportunity to explore if an early warning system can be developed based on an awareness of elephant population numbers. We have completed initial testing of an early warning device in conjunction with a local youth collaborative and are awaiting their data to determine if the sound-based device was effective at differentiating elephants from other wildlife or abiotic noise.

c. *Elephant Database*. The elephant ID database continues to grow with additional family groups, bull groups, and associations recorded. This is the first time that elephants have been catalogued on Rukinga Ranch; future analysis could reveal how movement of individuals varies seasonally and which bulls associate when crop raiding or if mature bulls tend to lead crop raiding groups.

d*. & e. Community Outreach & School Visits*. The established Facebook page entitled *Elephants and Sustainable Agriculture in Kenya* has grown to over 600 followers, and some shared posts have reached over 12,000 people. We update this site frequently; it provides a means to thank supporters of the project and direct them to places (such as the IEF donation page) where they can contribute to our efforts. At the request of volunteers, we have also established a fund to support the children of

Sasenyi Primary School adjacent to the study area, and a fund for donations directly to our project. These funds will be accessible for donations through the IEF website. The increased online traffic could make more people aware of IEF-funded projects, keeping elephant conservation in the forefront. The success of the school program this year was stunning; volunteers contributed enough to feed lunch to over 700 children for all of 2019 and into March 2020, as well as donating the funds necessary to establish year-round water access for the school.

f. Track Crop Damage. For the entire study to date, we have monitored larger mammal species entering farms and/or damaging crops. From the onset of the trials, it was observed that elands were doing damage in experimental fields. Analysis from all trials demonstrated that elands were frequent visitors, sometimes as often as elephants. This year as we started monitoring more areas in the community we saw larger areas decimated by elands. However, elephants always do considerably more damage. Though deterrents were designed to prevent elephants from entering, analysis also revealed that all active deterrents (except acacia) were effective against elands, despite their amazing jumping prowess. As elands are renowned for their "skittishness," this suggests that the movement of these barriers in the wind may be effective in preventing crop damage by elands. However, unprotected farms may incur damage from elands, which could be misattributed to elephants, and eland presence is often much harder to detect. Since farmers have erected home-made wind socks long before our study, we can utilize the knowledge of indigenous people, experimentally evaluate their means of deterrence, and add viable deterrent methods to the catalog of defenses against crop raiding. We will be examining whether the presence of eland might forecast raiding by elephants. We have also observed that damage to fencing structures is much higher when elephants or eland are aggressively chased away by community members, and when chased away from one area, some animals return to raid in others.

Elephant damage to farms usually consists of a combination of dung deposition, trampling, and consumption, yet through all years of our study, we have found only one case of elephant dung in the experimental fields. For T5 and T6, as we tracked elephants we noted locations of dung outside our experimental area seeing similar results. Consumption was responsible for the majority of crop mortality from elephants in T1 and T2, but farmers only lost 5% of their overall yield because of elephant raids. We are analyzing T3-T5 and completing data acquisition on T6.

(2) Tree Damage and Mammal & Bird Surveys

a. *Tree Damage.* We rechecked all 240 trees and determined that over 75% showed signs of new damage by elephants. This data set will provide information on how elephant foraging changes over time and if crop raiding fluctuations can be predicted by these changes. On a broader conservation scale, assessing the impact of elephants on the wild habitat will improve our ability to understand when and why elephants turn to crops for sustenance. In addition, as stated above, we will determine preferences for species and the relationship between waterhole permanence and elephant damage. If trees of value need to be protected, we will initiate tree wrapping or other viable practices.

b. *Mammal and bird surveys*. Our driving transects continue to reveal the distribution and density of a variety of species, including those of high conservation interest such as endangered Grevy's zebra and all vultures. Now that year three is completed, we are assessing the transect data as a comparative

opportunity to search for indicator species that coincide with crop raiding rates and will be altering our transect schedule accordingly to maximize data acquisition.

7. Numerical Impact on Humans and Elephants

Based on the 2009 National Census, the human population in Buguta sub-location was ca. 7,000 in 1,200 households. This is the area closest to our experimental fields. The region around the Wildlife Works wildlife corridor has a population of some 90,000 people. Tsavo National Parks have an estimated elephant population of 12,000-14,000 (ca. one-third of the Kenyan elephant population). Thousands of elephants are known to move through the Kasigau Wildlife Corridor, but reliable population estimates have not been determined prior to the present study; however, during the November-December months of 2017, the population of the elephants on the ranch was estimated at 700-800 from aerial surveys conducted by Wildlife Works pilot Keith Hellyer. During T3 in 2018, elephant numbers were about 1/6 of this amount, but the seasonal migration of elephants back into the ranch area during T4 showed numbers close to 2017 levels. Elephant numbers in T5 started at about 150 elephants on the ranch, and several new-born elephants have been sighted. However, the population escalated to over 600 when the drought lasted through October, and the ranch was one of the only sources of water in the area.

The four experimental farm blocks that we established had eight different families benefit from the leasing of their farms and the protection of their crops. Four additional farmers received beehive fences and also participated in a workshop teaching apiculture, a skill that can be passed to future generations. In addition, the community of Ngambenyi has received a front-line Kasaine fence, another area with high crop raiding in the corridor. Monitors have noted adverse reactions from elephants, and some farmers behind the fence are planting crops again for the first time in years. Most participating farmers had failed harvests in T5 due to unusual rain patterns and drought, but all farmers (except those in a portion of block 4) are currently expecting near record harvests.

8. Problems during the Project Period

Termites have destroyed several fence poles, even though they were initially treated with pesticides. The poles have been replaced, adding to our expenses. In addition, all cloths and ropes had to be replaced in T5, and a large portion of the supply budget was expended on building the new Kasaine fences. Fortunately, the existing Kasaine fences held up well and could be reused. Fourteen cameras have been stolen over the length of the project, and one each was added in T5 and T6 bringing the total to 16. However, this was the lowest numbers of thefts in our three years of operation, and twice farmers rescued downed cameras. This suggests our outreach program at the schools could also be having a positive impact. Bee farmers neglected to add excluder boxes to hives in T4, which could have led to limited honey production. We had to remind farmer about hive maintenance, but we are hopeful for a honey harvest soon. The project vehicle continues to have mechanical issues, but these have been addressed periodically. To date, we have solved or are addressing all problems that have arisen. We anticipate continued success of the project.

9. Evaluation of Success to Date

To date, the project has accomplished one of its main objectives by statistically demonstrating the deterrent effectiveness of the Kasaine strip fence alone and in combination with another deterrent. In addition, we have shown that chili fences alone are not successful in this area and after the conclusion of three trials of data on cloths without chili, results may suggest that movement of the flags and ropes, and not potency of the chili's, were responsible for the widespread efficacy of this deterrent. However, results could vary based on geography as Sasenyi is an extremely windy area. The frequency of elands in our experimental area was an unexpected but important outcome. Additional work is underway to assess the threat of elands to crop security, and the potential for elands to serve as a warning of elephant raiding. The possibility that fences with mobile components (e.g., cloths or metal strips) may be effective against elands is also important information for farmers and elephants, as elephants are predominantly blamed for the majority of crop raiding in this area. Additional trials are needed to increase sample sizes, potentially validating results and allowing us to improve efficacy by trying new methods and combinations. The elephant identification catalogues continue to grow, with many new individuals and families added in 2019. We also added unknown elephants from crop raiding incidents, which should be identifiable as the known individuals increase. We are delighted with the completed construction of the new deterrent methods as well as the addition of the fence in Ngambenyi, which improves our reputation with and support from the community. Support of the schools through the school lunch program may also be building confidence in our project with community members; this may help or already have helped stem the theft of our camera equipment. At the qualitative level, we hope to help facilitate greater awareness (and action) on how to deter elephants, and construct and maintain deterrents and assess whether community perceptions of elephants improve over time as part of community workshops. We will examine this quantitatively using data from surveys conducted by Wildlife Works in conjunction with this study and through the initiation of a workshop program which addresses key drivers of HEC. This will be a complementary project conducted by Lynn Von Hagen as part of her doctoral work at Auburn University.

As we continue to build the tree damage and the animal transect databases, we will investigate the relationship between these data sets and the presence of elephants and the prevalence of crop raiding. This is slated to be part of the MS thesis work by Sophia Corde. Transects continue to gather a considerable amount of information towards this goal. We successfully reevaluated 100% of surveyed trees, and showed additional or new types of damage including the loss of several trees this year.

All five Earthwatch teams from 2019 were extremely satisfied with their expeditions and all have expressed interested in staying current on developments within the project and their rankings made us as one of the **Top Ten Earthwatch Projects in 2019.** The establishment of the Sasenyi School Fund was just one way that former team members have demonstrated this willingness to stay engaged. We have several teams already scheduled for 2020. Our agreement with Earthwatch was extended through 2021 with our renewal for another three years due in November 2020. We are looking forward to another productive season of data collection in 2020. Our research group is growing with the addition of Ms. Sophia Corde who will be pursuing her Master's degree under Dr. Schulte at Western Kentucky University.

10. Next Steps

There is unlikely to be an affordable, sustainable, and ecologically friendly 'silver bullet' to reduce or eliminate crop raiding by elephants. Field experiments are time and energy consuming, but they are the only means to demonstrate scientifically that a particular deterrent or set of deterrents is successful and economically viable for rural farmers, who must contend with elephants and other causes of crop depredation. A clear benefit of a continued presence and commitment to reducing HEC is the conservation pay-off. People who live with elephants often see little value to elephants. By working with these people and their children and by incorporating a climate smart agriculture approach, we can change them from opponents to proponents of elephant conservation and sustainable practices in general.

Our next goals for the deterrent study in 2020 will be to continue monitoring beehive fences with farmers and replace chili + Kasaine fence with a new deterrent method and continue to monitor the success of the new iteration of the Kasaine fence, a double metal fence. We may add new locations to test new deterrents in T7, which will also improve our reputation with the community as the project expands to include more villagers. As part of Lynn Von Hagen's PhD thesis, we will be disseminating information on how to build and maintain these fences for local communities through workshop programs, which also will address key drivers of HEC as an expansion of the project. Her study has received separate funding from IEF for 2020. We evaluated an early-warning system that alerts the community about the presence of elephants. We are awaiting data so that we may correlate our early observations.

We will continue to grow the elephant ID database and determine how many elephants once or repeatedly crop raid into our experimental blocks. We are still identifying elephants from the last trial (T6). For the first time, we had confirmed reports of family groups raiding farms.

As we continue to build the tree and animal transect databases, we will investigate the relationship between these data sets and the presence of elephants and the prevalence of crop raiding and alter routines to maximize data collection. Climate-smart agricultural practices will also be one of our main priorities. We determined that the soil quality is poor in the Sasenyi area. Thus, the CSA plots were overwhelmingly successful. We will expand on our use of CSA techniques, which also should put additional pressure on the deterrent fences as the crops will be of higher quality. This should be a good test of their ability to deter elephants!

11. Human Interest Story

In preparing for her doctoral project, Lynn Von Hagen went to six different villages to interview farmers and hear stories about what it is like to live with elephants (often literally) in your back yard. Lynn is designing community workshop programs with the goal of reducing HEC while increasing sustainable livelihoods. Lynn and her team were welcomed with smiles and multiple handshakes, and usually the offer of cobbled together chairs under some makeshift shade; Kenyans are notorious for their welcoming spirit! Every story was moving, and often disheartening, especially given their living conditions with most of them in ragged clothing. However, there was one constant and striking theme to their stories: ***resilience***. Mr. Nguti (Fig. 2) from the village of Kisiminyi was ingenious in his

methods of trying to keep elephants out of his farm. He often stayed up late at night to protect his harvest. He wove together rope to create a giant slingshot that makes a noise like a whip when he uses it. He takes care not to hit the elephants for fear of angering or hurting them, but he said if you get the sound just right it will startle them and make them flee. He also had the brilliant idea of suspending a flashlight on a rope that swings with the wind. It makes it seem like someone is outside with a flashlight. Because elephants fear humans, the light has also worked well for him; however, the batteries are too expensive to keep it going for long. Since he lives near the border of two community ranches, he is hit hard every season by elephants and other wildlife too. Some crops he has had to stop farming because they are so favored by his late night visitors. He is hoping for some kind of help to keep the elephants away. One night he fell asleep while guarding, and elephants came right into his homestead area. When he awoke he had to flee inside to escape the elephants that chased him. He chuckled as he said they stayed right there (pointing nearby) and ate as much as they wanted. But despite the extra work and danger, he never wants to quit farming; he can't think of anything else he would rather do. Like many others, he does not want to see harm come to the elephants, he just wants to live a peaceful existence. Lynn's hope is that her workshop programs will give farmers like Mr. Nguti the knowledge and tools they need to reduce HEC and find a way to coexist with their oversized neighbors. . .it doesn't get more ***resilient*** than that.

12. Project Progress Summary (500 words)

Human encroachment and agricultural development have compressed and fragmented the ranges for African elephants. Negative encounters with people result in Human Elephant Conflict (HEC) with consequences including loss of biodiversity, damage to canopy trees, poor relations between local people and wildlife officials, loss of livelihoods, and injury or death to people and elephants. The most common form of HEC is crop raiding, which can be devastating for subsistence farmers. Our 2019 project had two main objectives. 1) To gather more data on the effectiveness of traditional and newly devised deterrent fences. This includes further test of the new Kasaine fence and its derivatives, other fence ideas, monitoring elephant behavior and demographics, creating an outreach program and conducting school visits, and tracking all sources of crop damage. 2) To continue our data collection and test new hypotheses on findings to date. This includes monitoring trees for damage by elephants, surveying larger mammal and bird species, and assessing eland as a potential indicator species of elephant damage and an underreported threat to livelihoods. This project is part of a larger study involving Earthwatch volunteers on climate smart agriculture practices for sustainable farming and the perpetuation of wilderness in the Kasigau corridor between Tsavo East and West National Parks, Kenya. In year three, we maintained four experimental blocks of eight fields each with deterrent fences and corresponding controls in each block and replaced two past deterrent methods with new fencing. Harvest was nearly a total loss in Trial 5, though the ongoing Trial 6 is having bountiful harvests after near record and early rains. We devised a double Kasaine fence, which preliminarily appears to be more effective than the single strand or combined chili + Kasaine fence. We initiated our first Climate-Smart Agriculture experimental plot for T5 and started a second in T6. In 2019, we hosted five Earthwatch volunteer field teams and already have several scheduled for 2020. The volunteers assisted us with changing and processing camera images from the crop raiding experiment, performed wildlife transects, located and documented elephants, monitored and create two new CSA plots under the direction of co-PI Dr. Urbanus Mutwiwa, and assisted with tree rechecks. We have made excellent

progress on our major and sub-objectives. Ms. Lynn Von Hagen returned in May to begin data collection related to her PhD thesis and will be back for 2020 and 2021 to continue work on the project. She has also presented the results in a seminar at her alma mater, Austin Peay State University in April 2019, and at the IEF Conference in Limpopo in October. In August 2019, Dr. Schulte presented results at the annual meeting of the Animal Behavior Society. Our video submission was one of the winners in the first IEF video contest. Mr. Bernard Amakobe and Simon Kasaine, employees of Wildlife Works under the direction of Dr. Mwangi Githiru have been invaluable collaborators in the success of the project to date.

13. Project Progress Summary (50 words)

Elephant crop raiding is the most pervasive and economically damaging interaction between humans and elephants. We experimentally tested several deterrent methods for effectiveness while also creating an elephant database, assessing tree damage caused by elephants, measuring biodiversity, and tracking crop raiding incidents in the Kasigau wildlife corridor of Kenya.

14. Organizations involved

The International Elephant Foundation (https://elephantconservation.org/), the Richard Lounsbery Foundation (https://www.rlounsbery.org/), the Earthwatch Institute (http://earthwatch.org/), Save the Elephants', Elephants and Bees Project (http://elephantsandbees.com/), Western Kentucky University (https://www.wku.edu/), Wildlife Works (http://www.wildlifeworks.com/saveforests/forests_kasigau.php), Jomo Kenyatta University (http://www.jkuat.ac.ke/), and Auburn University (www.auburn.edu).

15. Financial Report – Final 2019

Item	Budget[1]	Expenditures	Cost
Travel (includes Video Award of $500)	$7550	Housing – Rukinga Ranch Company Ltd	$3200.00
		Board (per diem)	$578.00
		Board (per diem)	$1830.00
		Board (per diem)	$1891.00
		Board (per diem)	$1737.00
Equipment, Supplies, Vehicle	$2950	Camera traps and related supplies (B&H Photo, Amazon, Walmart)	$911.65
		National Commission for Science (permit/visa)	$329.74
		Wire transfer fees	$22.00
Total	$10,500.00	All Expenses to date	$10499.39
Remaining			$0.61

[1]This does includes the $500 from the IEF video award. The remaining balance of $0.61 is requested to be rolled into the 2020 award.

16. Digital Images

Figure 2. Mr. Nguti from Kisiminyi demonstrating how he uses a home-made slingshot to scare away elephants from his farm.

Figure 3. Hired motorcycles delivered a parade of food to Sasenyi Primary School when flooding made the road to the school impassable by car. Thanks to past volunteers and the facilitation of IEF, the program feed school children throughout 2019 and 2020 and brought a permanent water source to the school

Figure 4. A beehive fence farm with Mt. Kasigau in the background. Corns in trial 6 grew tall and were harvested after record rains.

Figure 5. Volunteers help repair sections of Kasaine fence at the new Ngambenyi location, a 1K long metal fence sponsored by Wildlife Works to protect the community.

Figure 6. An elephant in Rukinga Ranch takes a drink at sunset from a refurbished cattle tank during the drought at one of the only permanent water sources, which drew over 600 elephants to the ranch in mid-2019.

17. Video Clip

We submitted a 5.5-minute video for the IEF Video Award contest.

18. Presentation / Publication Plans

Conferences

2019 Animal Behavior Society
2019 International Elephant Foundation

Planned Manuscripts

Von Hagen RL, Kasaine S, Githiru M, Amakobe B, Mutwiwa UN & Schulte BA. Metal strip fences for preventing African elephant (*Loxodonta africana*) crop damage in the Kasigau Wildlife Corridor, Kenya. In review, *African Journal of Ecology*.

Von Hagen RL, Norris P & Schulte BA. Quantifying capsaicinoids from chili pepper and motor oil mixtures used in elephant deterrent fences. Submitted, *Analytical Methods*.

Von Hagen et al. Eland as substantial crop raiders. In preparation.

Published

Von Hagen L, Kasaine S, Githiru M, Amakobe B, Mutwiwa U & Schulte BA. 2019. Search for solutions to human-elephant conflict. Journal of the Elephant Managers Association 30(2), 85-90.

19. Website, Blogs, Social Media Accounts

https://www.facebook.com/ElesKenya (**note this has changed**)
https://wkunews.wordpress.com/2017/02/08/elephant-research-kenya/
http://www.bgdailynews.com/news/wku-professor-gets-funding-to-study-human-elephant-conflict/article_c65bfb09-dfa3-5e3a-b21a-c978229dbe10.html
https://www.facebook.com/permalink.php?id=108627465679&story_fbid=10155055396185680
https://elephantsinkenya.wordpress.com/
http://earthwatch.org/expeditions/elephants-and-sustainable-agriculture-in-kenya
http://wkuherald.com/news/professor-to-research-elephants/article_195bd418-35eb-5a07-ba30-a701a6ceea93.html
http://targetednews.com/nl_disp.php?nl_date_id=833129
http://www.epagepub.com/publication/index.php?i=419814&m=&l=&p=42&pre=