Human voices as a deterrent for wildlife in farmlands – an acoustic study

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Abstract

Conservation conflicts are an increasing global problem with wildlife having an adverse effect on humans and vice versa. For example, wildlife destroys crops that are an important source of livelihoods for humans, and humans destroy wildlife habitats. Human and wildlife co-existence depends on limiting these adverse impacts, which can be achieved through conservation and wildlife damage management. In the area surrounding Njukiri forest in Embu, Kenya, farmers face the problem of wildlife from the forest foraging in their farms and destroying their crops. Primates such as olive baboons (*Papio anubis*), vervet monkeys (*Chlorocebus aethiops*) and syke's monkeys (*Cercopithecus albogularis*) cause the most extensive damage.

The farmers spend both time and money scaring the wildlife away from the croplands, but still incur big losses to their crops. This study aimed at analyzing if acoustic deterrence in the form of human voices could be sufficient to limit the crop damage caused by wildlife, at least temporarily. Experiments using mixed recordings of farmers talking and shouting at wildlife were conducted at farms located close to the Njukiri forest. At each site, a bait station was maintained, and wildlife appearances at the bait station were recorded using motion-triggered cameras. Repeated periods with and without acoustic deterrence were evaluated at each site. However, after comparing the mean rates of animal appearance between sites and periods, no significant evidence of the effect of sound on animal appearance was found.

Keywords: acoustic deterrence, human-wildlife interaction, wildlife management, crop damage

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Abbreviations

A	After last experiment. Site contains only camera and bait.
ANOVA	Analysis of Variance
B	Before experiment. Site contains only camera and bait. No prior experiment has been conducted.
I	Control in between experiments. Site contains only camera and bait, but experiments with sounds have been conducted earlier.
E	Experiment. Site contains camera, bait and a speaker charged with a solar panel that displays sounds at random intervals.
KWS	Kenyan Wildlife Service
ME	Maybe experiment. Site contains camera, bait and a speaker charged with a solar panel that displays sounds at random intervals. The speaker is likely to have stopped playing sometime during this period, but unknown when.
REML	Restricted maximum likelihood
SLU	Swedish University of Agricultural Sciences

1. Introduction

1.1 Human - Wildlife interactions

"The philosophy of human-wildlife coexistence is based on the concept that wildlife populations can only remain abundant if humans and wildlife can live together on the same land with neither having an adverse impact on the other."

– Michael R. Conover.

Conservation conflicts are an increasing global problem with a growing and expanding human population and infrastructure causing negative impacts on biodiversity but also human livelihoods and well-being (Redpath et al. 2013). Human-wildlife co-existence depends on a reduced adverse effect of wildlife on humans and vice versa (Conover & Conover 2022). Conservation biology and wildlife damage management are tools to address the challenges for human-wildlife co-existence. Wildlife damage refers to a species causing damage to an object so that a person gets adversely affected, or when a person is indirectly and negatively impacted by the wildlife, for example by fear of getting hurt (Conover & Conover 2022). Crop damage is one major cause of negative interactions between farmers and wildlife (Evers et al. 2022).

Conservation conflicts are globally widespread, but not evenly distributed since they depend on the proximity to wildlife and varies with the time of the year (Mekonen 2020). Wildlife can if managed correctly provide multiple positive values to humans in the form of physical utility, monetary-, recreational-, ecological-, existential- and historic value, but these benefits and liabilities do not affect society equally (Conover & Conover 2022). For example, a country can benefit from wildlife tourism, but a local farmer might not get any economic benefit from the tourism, except a monetary compensation for damages, and might instead risk both life and crops daily. A big part of the challenge when addressing human-wildlife conflicts is therefore understanding the human dimension with both social, cultural, political, economic, and legal complexities (Conover & Conover 2022). Experiences of problems with wildlife damages have often to do not only with the damage itself, but also the perception of risks and lack of control in addressing the issue. For example, in an area where the wildlife is protected and the government does not abide in protecting the farms with subsidies, barriers, scaring methods or compensation, people can feel helpless facing the issue since they might not feel listened to and left to deal with the problem on their own. Many conflicts that can seem to be about species impact are also linked to attitudes and values that originate from social and cultural history where information might be passed down from one generation to the next (Redpath et al. 2013). It is therefore important when working on conservation conflicts to educate people about the positive aspects of wildlife, conservation and management while simultaneously limiting damages in crops using for example boundaries like fences or scaring methods. Finding cost-efficient, practical, and available solutions to limit wildlife damage is an important part for human-wildlife co-existence, both from a human and a wildlife perspective.

1.2 Wildlife management with acoustic deterrence

Most wildlife damage occur in the absence of humans, as people typically scare away animals through their mere presence or with e.g., shouts, gestures, or movements. Animals rely on multiple sensory cues to detect the presence of and evaluate a possible threat. A single cue, such as the sound or the smell of a human (or other predators), may suffice to alert the animal and sometimes also cause a flight response (Bhardwaj et al. 2022). Studies suggest that humans are perceived by most wild animals as a frightening top-predator, hence wildlife typically avoids being near humans (Crawford et al. 2022). A method that has been used in Sweden and other countries is acoustic stimuli to elicit a flight or avoidance response in wildlife (Bhardwaj et al. 2022). This has for example been used with a focus on bat conservation (Gilmour et al. 2020) to decrease mortalities at windfarms (Romano et al. 2019), to prevent road and railway collisions with mammals by making the animals leave the area of danger (Babińska-Werka et al. 2015, Shimura et al. 2018), and to reduce crop damage caused by ungulates (Widén et al. 2022). A study in South Africa evaluated different methods to deter primates from crop foraging on commercial farms using the sounds of snakes, leopards, bees and humans (Evers et al. 2022). The study found that human sounds reduced the number of days baboons visited a bait station, but not their foraging duration, while leopard and bee sounds reduced the foraging duration of vervet monkeys.

1.3 Overview of the wildlife problem in Kenyan farms.

In 2021, Kenya's human population was approximately 53 million people. As of 2020, 48.5 % of the country's land area is agricultural land and 6.3 % is forest (World Bank 2023). A considerable part of the population in Kenya is dependent on agriculture; most farming in Kenya occurs on smallholder levels, and many live with small economical margins. Around 80% of all farms can be categorized as small farms with a size of just over 0.5 ha according to Koomen (2018). Most farms are family farms, with the majority of work being done by family that usually lives next to the farm and are more or less constantly present. The family uses the product for their own food security and might sell the surplus. The size of the farms in Kenya is generally decreasing due to an increase in the rural population and the aspect of inheritance. The farms are often smaller than the required cropland to earn a living income. Koomen (2018) gave the example that in Nyando, the average farm size is 1.5 ha, which needs to increase to 3 ha to reach the poverty line, and 8 ha for the farmers to earn a living income. 29.4 % of Kenya's population was living on less than $2.15 a day (2017) and 27 % of the population was undernourished as of 2020 (World Bank 2023). Maize is Kenya's staple food and is grown in 90 % of the farms with beans being the most important legume (Kenya Food Crop Directorate*,* 2023) Every harvest is important to a farmer and any crop loss can greatly impact a household, regardless of whether it is caused by crop diseases, pests, weeds or wildlife.

Only a small part of Kenya consists of forest habitable for wildlife. Where protected areas like forests and agricultural lands meet, human-wildlife conflicts will occur if not managed properly. For a small, local, self-sufficient farmer, like most farmers in Kenya, a loss of crops is not only an economical loss, but a potential risk of food deprivation and undernourishment.

1.4 Local problems at farms around Njukiri forest

This study was conducted in the farming community around Njukiri forest in Embu. To understand the problems that the farmers face, 90 interviews were conducted with the local farmers, with the help of staff and students from the University of Embu for interpretation. The interviews concluded that most people have a very negative or negative view of wildlife because of the damage to crops (Appendix 1). During certain periods of the year, and depending to the state of the crops, farmers perceived that they had visits of wildlife daily. People in general seemed to have the most severe issues with olive baboons (*Papio anubis*), vervet monkeys (*Chlorocebus aethiops*) and syke's monkeys (*Cercopithecus albogularis*). The primates live in groups and might not only consume the crops, but also uproot and cause general destruction, while simultaneously being difficult to scare off and hiding in the trees around the farms.

Opinions on how to best manage the wildlife varied between farmers. The farmers used different methods for scaring the wildlife: scarecrows, creating sounds by banging on metal, screaming, and chasing the wildlife, keeping dogs, throwing stones and dirt, and in some cases when no other methods gained result, poisoning, or catching and killing the wildlife even though it is illegal. According to the wildlife act of Kenya, the farmers can contact the Kenyan Wildlife Services (KWS) if they experience problem with the wildlife (Kaai et al. 2013). They can also claim compensation from the County Wildlife Compensation Committee for loss of life, injury or damage to property caused by wildlife, but no compensation is paid for losses caused by primates. Instead, farmers are supposed to time their harvest to control wildlife foraging on grains such as baboons or vervet monkey (ibid.).

To prevent crop damage, many farmers spend a significant part of their day guarding their crops and scaring away wildlife. Some farmers hire people to guard their farms and protect the crops during sensitive periods if they have the economic means to do so. Protecting the crops from wildlife also poses a potential risk to the farmers. Olive baboons might, for example, hurt dogs or children, and when people threw stones to scare them away, some baboons would throw stones back. One of the interviewed farmers had lost a child in a drowning accident when the child tried to chase away the wildlife.

1.5 Problem statement

Minimizing crop damage with the currently applied methods is costly, time-consuming, and potentially dangerous for the local farmers around Njukiri forest. Meanwhile, farmers still run a high risk of losing considerable portions of their crops. This leaves the farmers in a vulnerable position with a negative perspective of wildlife, while simultaneously potentially hindering future work of conservation if animals are seen as pest and therefore trapped and killed. The loss of crops and negative attitude it causes towards wildlife is a big problem from a human perspective, and potentially also from a conservation perspective. New methods of keeping the wildlife away from the farms are therefore needed.

1.6 Objectives

The purpose of this study was to evaluate whether acoustic cues alone are enough to, at least temporarily, keep wildlife away from attractive crops, thus proving useful as a management tool. To achieve this, prerecorded human voices were displayed during irregular time intervals at selected attraction points, and the response and the presence of animals were recorded on video and photo. The study was set to investigate whether and for how long these sounds would be sufficient without the visual presence of humans. If the animals were unable to differentiate between recorded and real sounds and anticipate the human presence even when they only hear the recorded sounds, crop damages could be reduced.

2. Methods

2.1 Time frame

Data collection was conducted over a 2-month period starting February 2023, with a two-week break between February 21 and March 6, due to logistic reasons. By March 11, most farmers had harvested their crops. From the first rain on March 14 and through the following rain season, a lot of sowing and planting occurred. During the study period, both the mango season and the maize season passed.

2.2 Research area

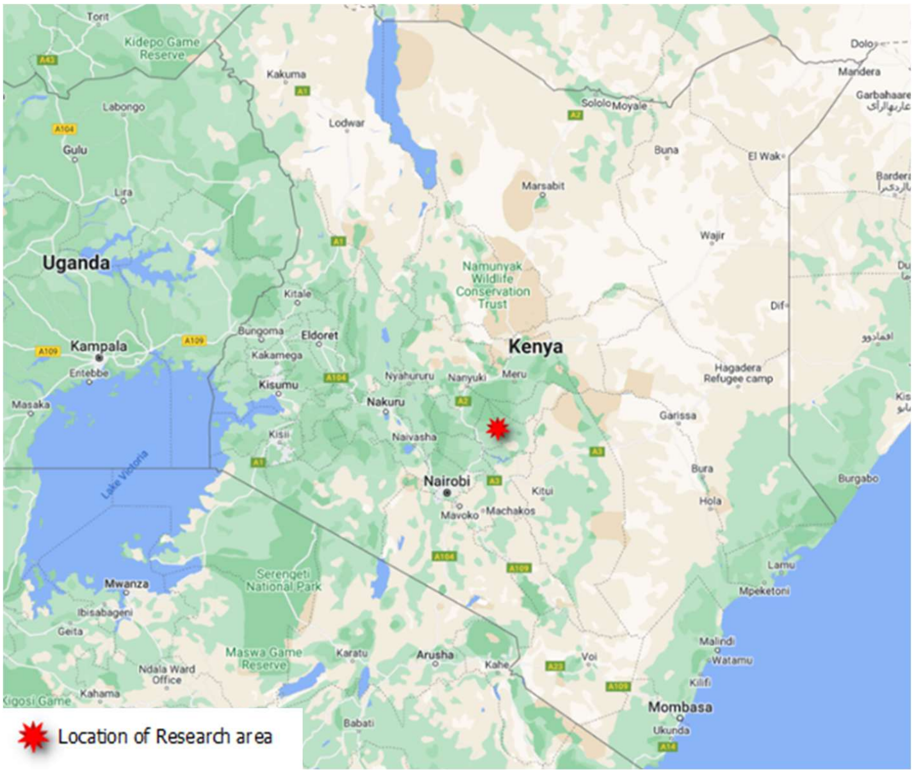

Figure 1. Map over Kenya with location of research area marked with a red star.

Njukiri forest is located in Embu County, in the central part of Kenya south of Mt. Kenya (Figure 1). It is in the tropical savanna climate zone, located around 1500m above sea level.

The study was conducted at 29 different sites on farms located in the vicinity of Njukiri forest (Figure 2). The farms all had similar crops, with maize, beans, bananas, and macadamia constituting most of the farmers' main crops. Not all sites were active throughout the entire research period, as some sites had to be abandoned and replaced by other sites. This was due to theft of equipment, among other reasons. All farms were located within 500 meters from the forest edge. The closest distance between different sites was 50 meters, but most sites were situated further apart (Figure 2).

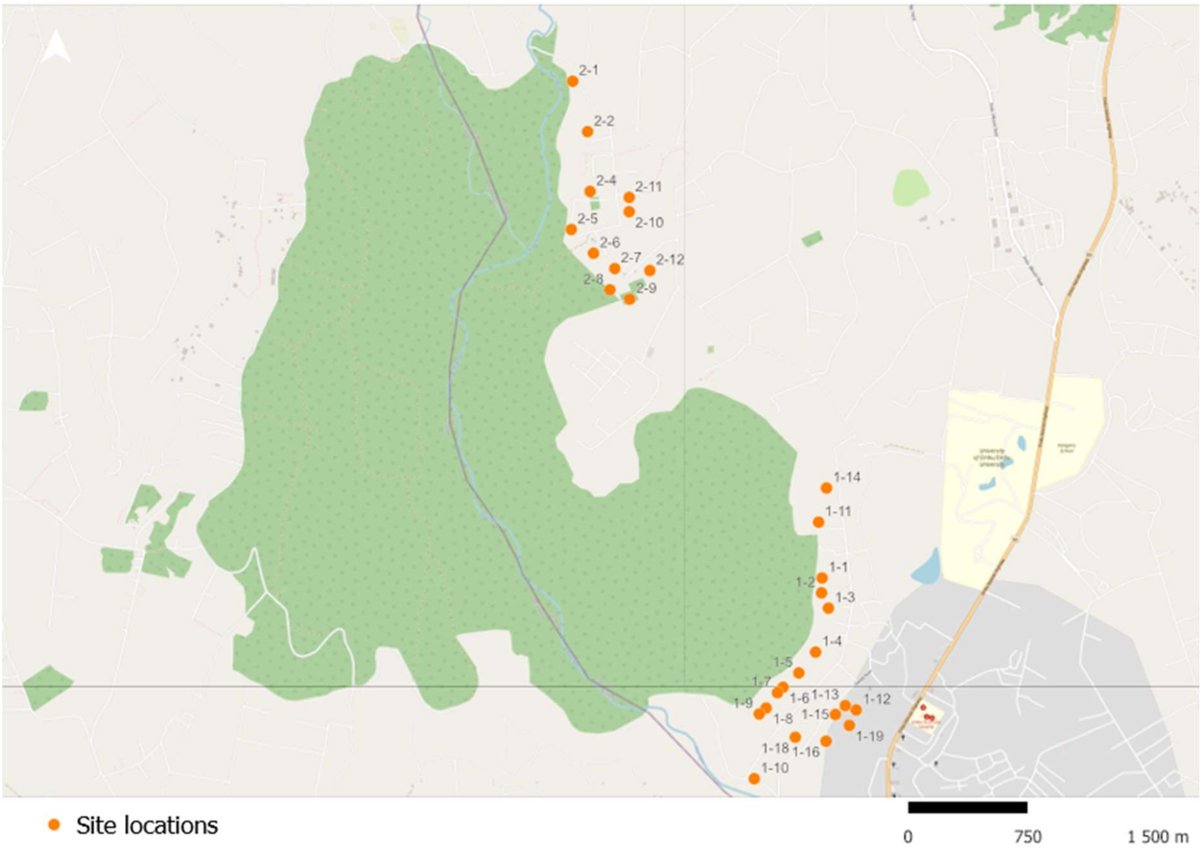

Figure 2. Locations and labelling of research sites around Njukiri forest. Only sites where any wildlife was observed in the study are shown.

2.3 Material

For the study the following equipment was used:

- 26 cameras, Denver WCT-8010 with 2 memory cards each.

- 15 weather resistant speakers, Denver bts-110NR with internal battery and SD memory card.
- 15 solar panels for recharging speakers.
- Bait (bananas, mangos, and maize).

2.3.1 Acoustic samples

The recordings of human voices used in the study contained shouts and spoken language of local farmers and were recorded by a University of Embu student that speaks the local dialect. Sound volume was adjusted to match "normal" conditions, mimicking a human present at the site. The different sound recordings were then concatenated into one sound file with a random mixture of voice recordings and pauses, with voice recordings of approximately 40 seconds at a time and pauses varying from 30 seconds to 30 minutes, to create an irregular and unpredictable display pattern during the day (see also Appendix 2).

Recordings of male voices and of mixed male and female voices were used. This choice was made since the interviews with the farmers had suggested that olive baboons may neither fear nor avoid females and children. To exclude the individual effect of a single sound, each phrase was recorded in at least 6 different versions to produce a sufficiently large variability in sound recordings so that many repetitions of the same sound during a day were minimized. The final audio file was approximately 5 hours and played on repeat to create an irregular and unpredictable display pattern during the day that did not repeat the same sound at the same time each day. The recorded sounds were also verified with the local farmers in order to keep it as close as possible to the original sound animals experience when the farmers are present.

2.3.2 Camera settings

The cameras used were of the model Denver bts-110NR. The cameras were first set to have a 1 minute time-lapse to have a picture taken every minute, but as this used up too much battery, settings were therefore changed to motion-trigger with video, with a delay-time of 30s between activations.

2.3.3 Bait

Bait was used to attract the animals to the cameras and speakers. The same type of bait was used for all sites at any given time, but as availability changed, different bait was used over time (Table 1). Farmers were requested to replenish the bait in case animals consumed bait at the station, to ensure that there were a constant number of bait present at each site.

Table 1. Time intervals of when different type of bait was used.

Date	Bait
2023-02-07 – 2023-02-20	4 mangos, 5 bananas
2023-03-07 – 2023-03-13	2 maize
2023-03-14 – 2023-04-10	2 maize, 3 bananas

2.4 Experiment design

Table 2. Description of the different states.

State	Description
A	After last experiment. Site contains only camera and bait.
B	Before experiment. Site contains only camera and bait. No prior experiment have been conducted.
I	Intermediate control in between experiments. Site contains only camera and bait, but experiments with sounds have been conducted earlier.
E	Experiment. Site contains camera, bait and a speaker charged with a solar panel that plays sounds at random intervals.
ME	Maybe experiment. Site contains camera, bait and a speaker charged with a solar panel that plays sounds at random intervals. The speaker is likely to have stopped playing sometime during this period, but it is unclear when.

The set up for each site varied between different states (Table 2). All sites were initiated with a bait station and a camera to record the activity of the wildlife before interference with the speakers. This state is referred to as the Before (B) state. Some of the sites were then equipped with a speaker that displayed sounds repeatedly at irregular intervals. This is referred to as the Experiment (E) state. The other half of the sites were used as controls. Each site was then changed between experiment and control with a few days' intervals (Appendix 2). Controls in between experiments at a site are referred to as Intermediate (I), and controls after the last experiment for a site are referred to as After (A).

Baits, cameras, and speakers were checked on a 2-5 day basis and the states could then be exchanged. The farmers themselves also checked the bait and speakers between visits, replenishing bait when needed.

2.5 Co-operation with farmers

The local farmers participating in the study were provided with bait (maize, mangos & bananas) to attract common wildlife. They did not receive any economic compensation but were encouraged to participate and received small tokens of appreciation to acknowledge their help and contribution at the end of the project. In the beginning it was difficult to find farmers to participate. Some farmers were reluctant to participate due to the fear of being responsible for stolen or damaged equipment and lack of compensation, and only the ones positive about the project were elected to participate. As the project progressed, people got to learn more about the project and were more curious and interested in participating and people would ask to be considered for a site.

2.6 Data processing

The recorded data was reviewed manually. Occurrences of wildlife were documented with *file-name, date, time, site, state, type of animals, sound playing and bait present.* If the observation occurred during an E state where there had been some form of issue with the equipment, such as a speaker failing, it was marked as Maybe Experiment (ME) (Table 2). To analyse the results with respect to the states B, E, ME, I and A, the data for each site was divided into periods depending on the state. These are referred to as B-, E-, ME-, I- or A-periods. Observations of *humans* and *dogs* were also recorded. Some secondary data features, such as various durations, were computed using Python. QGIS (3.26.3) was used to compute the distances between the sites and the forest. Analysis of the acquired data set was then conducted using JMP. Based on these periods and their average rates of wildlife observations, statistical analysis was conducted as is described in the remaining subsections.

2.6.1 Data selection

Sites with no wildlife observations were discarded from further analysis. Sites with no Experiment period (E period) were also discarded. One outlier was also removed from the data which was an A period at site 2-1, stretching over 23 days due to lack of speakers at the end of the research period. The weeks after the break were also analysed separately from the whole data set, due to varying conditions before and after the break in experiments.

2.6.2 ANOVA

ANOVA tests (Analysis of Variance) were performed to evaluate if a difference could be observed between the states with regards to the mean animal visits per hour rate for each period.

2.6.3 Fit Model standard least squares REML

A standard least squares model was fitted to describe the average visit per hour rate. The data was weighted using *period duration in days.* A restricted maximum likelihood (REML) was used instead of maximum likelihood to avoid variance bias (Oskolkov 2020).

3. Results

3.1 Variation within site and period

There is a great variability in both period length and how long the different sites were active. Some sites could only be used for shorter periods due to thefts, either at the site or surrounding sites. The site that was active for the shortest time was used a little less than a week, whereas the longest active site was used for 34 days. The state (B, E, ME, I, A) and the length of each period duration varied also, due to multiple reasons including malfunctioning or ill managed equipment or theft which in general led to shorter E periods compared to the other periods, and longer A periods since only three functioning speakers remained in the end. A summary of the results from the data collections are displayed in Table 3 and Table 4.

The shorter length in the E period (Mean 2.94 days, Std 1.79 days) compared to the longest periods B (Mean 5.86 days, Std 2.70 days) and A (Mean 10.08 days, Std 5.71 days) makes it important to take in the duration of the period when analyzing the effect of the human sounds (Table 3).

Table 3. Overview of the collected data per period summarized for all sites. The data contains information about the duration of a period, the number of animal-, human- and dog visits and how they vary between different states.

State	Period duration in days Mean±Std (min, max)	No. animal visits Mean±Std (min, max)	No. human visits Mean±Std (min, max)	No. dog visits Mean±Std (min, max)
B	5.86 ± 2.70 (1.96, 13.88)	2.5 ± 3.62 (0, 13)	19.38 ±15.25 (5, 66)	4.81± 6.15 (0, 20)
E	2.94 ± 1.79 (0.35, 6.99)	2.41 ± 3.13 (0, 16)	13.93 ± 11.69 (2, 49)	4.03 ± 6.77 (0, 24)
ME	3.01 ± 2.11 (0.54, 6.90)	3.59 ± 5.75 (0, 20)	13.82 ± 23.20 (0, 124)	5.04 ± 7.05 (0, 26)
I	3.62 ± 3.37 (0.38, 13.08)	4.88 ± 6.97 (0, 29)	13.08 ± 13.67 (1, 63)	5.30 ± 5.88 (0, 20)
A	10.08 ± 5.71 (0.40, 20.00)	12.62 ± 14.89 (0, 49)	31.38 + 30.91 (0,130)	19.31 ± 27.04 (0,83)

Table 4. Overview of the collected data per site: how long they were active, their location relative to the forest, and the number of human and dog visits per site.

Site	Distance to forest (meter)	Total duration (days)	No. human visits	No. dog visits	Average human visits per day	Average dog visits per day
1–1	50	31.74	203	1	7.83	0.041
1–2	50	8.74	26	2	3.07	0.33
1–3	100	21.94	79	7	3.13	0.52
1–7	90	6.90	150	17	19.20	1.71
1–11	110	17.08	106	10	13.75	1.26
1–12	490	20.98	60	0	3.63	0
1–13	170	31.71	80	26	3.41	0.69
1–14	210	31.79	114	2	3.23	0.02
1–15	430	24.93	144	43	7.57	1.66
1–16	520	24.93	61	100	2.60	5.75
1–18	370	16.78	28	30	2.30	2.54
2–1	50	23.97	143	18	5.91	0.72
2–2	140	33.96	150	17	4.60	0.50
2–4	180	32.03	91	92	3.05	2.30
2–5	180	22.10	101	118	5.93	4.95
2–7	140	17.27	38	43	1.86	2.51
2–8	20	34.14	99	119	3.07	2.65
2–9	90	32.09	55	16	1.72	0.55
2–10	410	32.02	72	33	2.59	1.00
2–11	420	34.00	93	61	3.06	1.46
2–12	280	15.19	38	20	3.13	0.88

3.2 Animal observations per hour

Comparing the number of visits over time, including all data there seems to be a significant negative trend in wildlife visits over time for the B periods (Figure 3). The B periods should not have been affected by the presence of experiments since no sound had yet been played at these sites during these periods. However, when only including the data after the break (Figure 4), no pattern with animal visits per hour decreasing over time can be seen. This acts as motivation not to include the data before the break, since the majority of the B period data was collected before the break, and a systematic variation in wildlife abundance before and after the break could therefore introduce undesired biases.

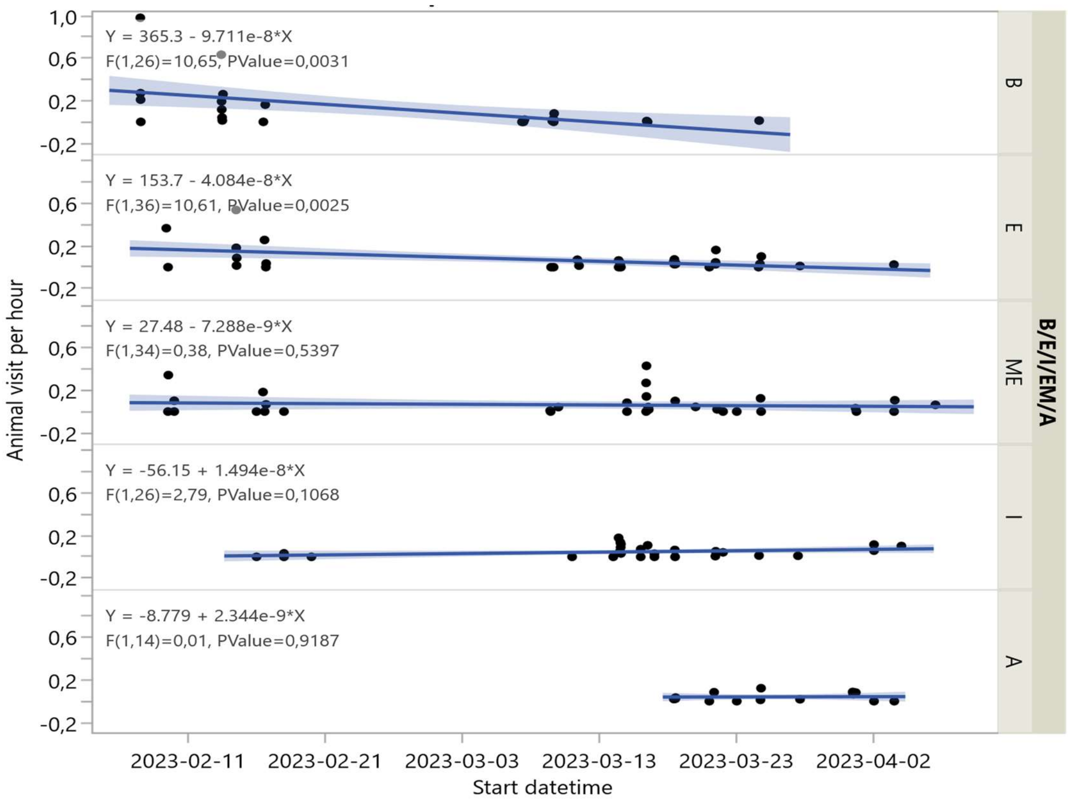

Figure 3. Scatter plot showing animal visits per hour vs date of visit, separated by state, for the entire research duration. Linear fits with standard errors are also shown. A trend of decreasing wildlife visit rate with time is observed for state B.

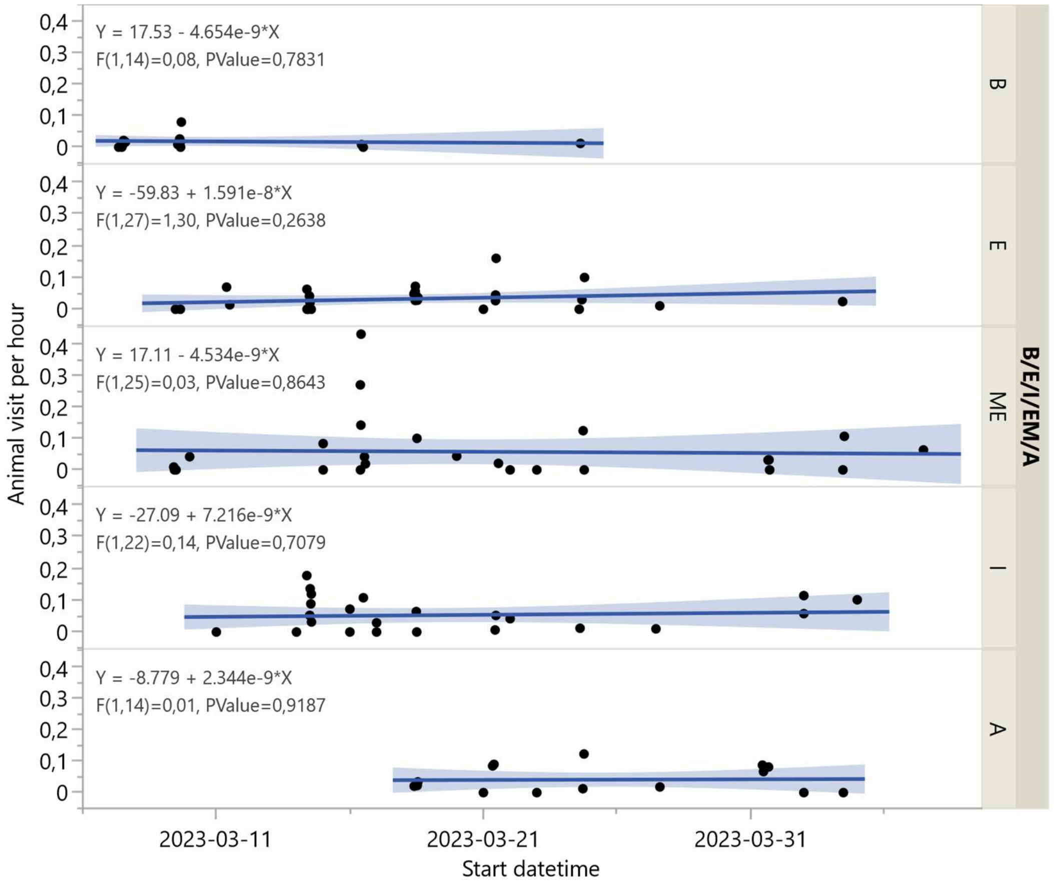

Figure 4. Scatter plot showing animal visits per hour vs date of visit, separated by state. Only data gathered after the break is included. Linear fits with standard errors are also shown. No trend of increasing or decreasing wildlife visit rates is observed for any of the states.

Conditions varied greatly between the start of the study, February 7, and after the 15-day break on March 7. Before the break, a different type of bait was used (Table 1), and all cameras were set to timelapse. There was also more food available on the farms before the break because it was the peak of the mango season, it was just before harvest and just before the start of the rain period. For these reasons, the data collected before the break was excluded from the remainder of the study, apart from one of the ANOVA tests.

3.3 Effect of distance to forest

There appears to be no significant trend in relation to distance to the forest (Figure 5). Further, there does not seem to be any significant correlation between distance and wildlife abundance, at least within 550 m of Njukiri forest.

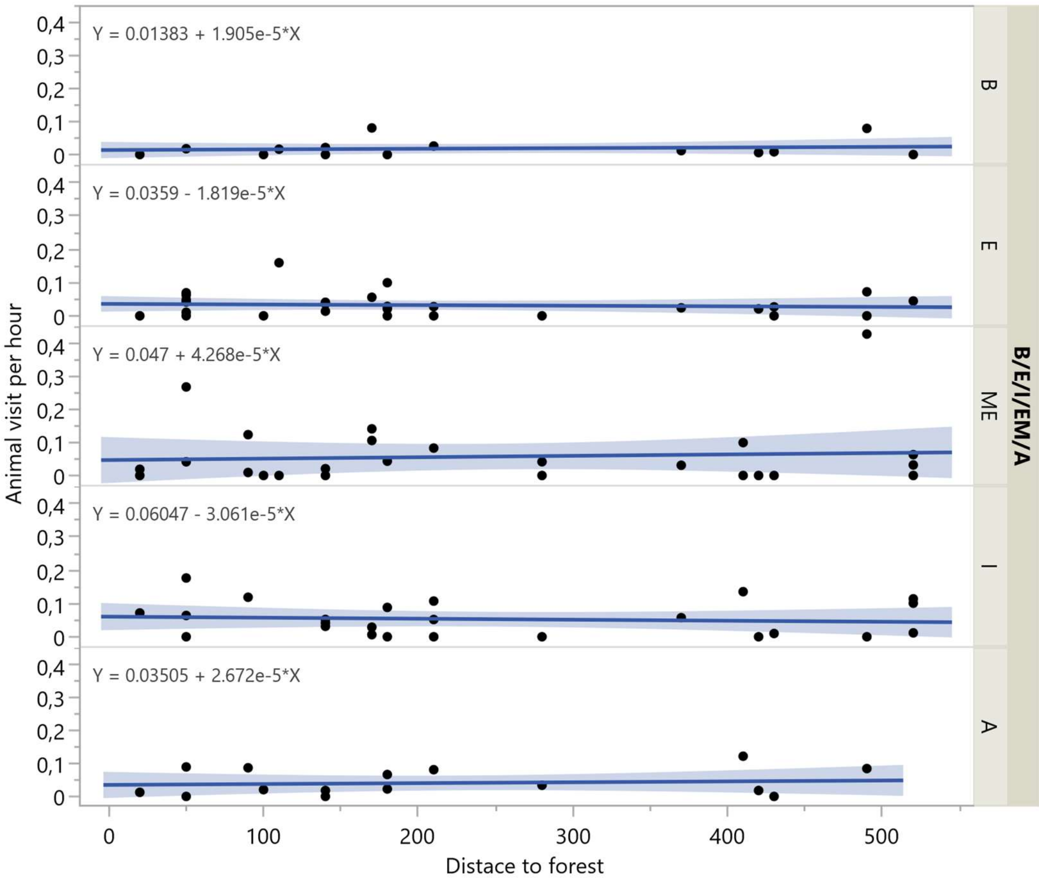

Figure 5. Scatter plot showing animal visits per hour vs distance to forest for each period and site. Only data gathered after the break is included. Linear fits with standard errors are also shown. No trend of increasing or decreasing wildlife visit rates is observed for any of the states.

3.4 Comparison of effects of states

State B has a notably higher mean visitation rate compared to the other states when all data is considered (Figure 6, Table 6). On the other hand, State B does not differ notably from the other states considering only the data gathered after the break (Figure 7, Table 8). According to the ANOVA tests, there are no statistically significant differences between the states compared to within the states, neither when excluding nor including the periods before the break (Tables 5 and 7). Hence, the ANOVA tests could not infer that the recordings acted as a deterrent for the wildlife. It is important to note that the ANOVA test doesn't take the period length into account, only the number of periods in each state.

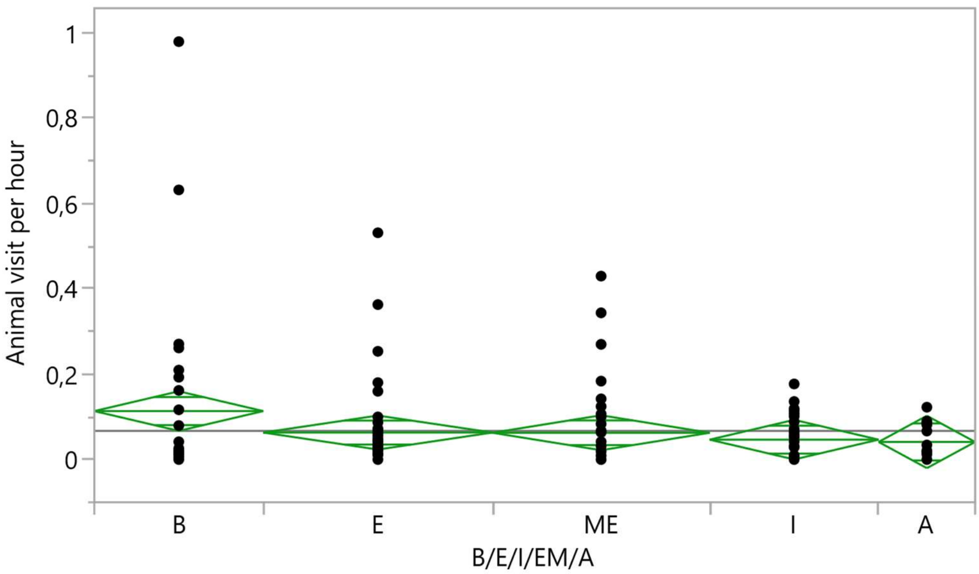

Figure 6. ANOVA test showing the distribution of Animal visits per hour. The result is based on the data from the whole research duration. The calculated mean values are displayed in the graphs marked in green. B has a notably higher mean than the other states, but the difference is not statistically significant (Table 5).

Table 5. Analysis of Variance from ANOVA test with data from the entire research duration. The state variable has no significant impact on the model.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
State	4	0.084	0.021	1.363	0.250
Error	141	2.165	0.015		
C.Total	145	2.249			

Table 6. Result from fixed effect test from ANOVA test with data from the entire research duration, including estimates, standard errors and confidence intervals of the mean animal visit rate for each state.

Level	No. periods	Mean	Std Error	Lower 95%	Upper 95%
B	28	0.113	0.023	0.067	0.160
E	38	0.063	0.020	0.023	0.103
ME	36	0.063	0.020	0.021	0.103
I	28	0.046	0.023	0.000	0.093
A	16	0.041	0.030	-0.020	0.102

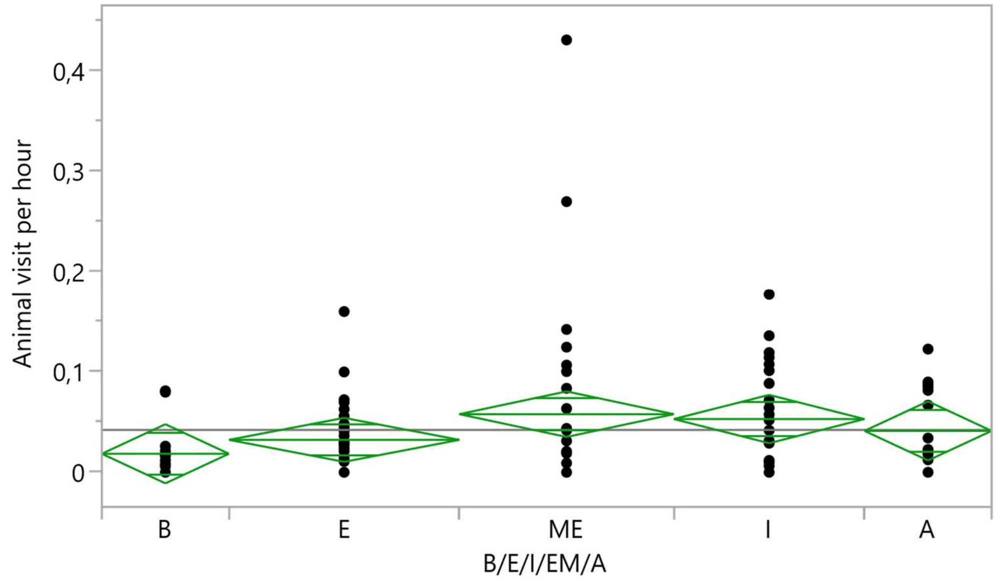

Figure 7. ANOVA test showing the distribution of Animal visits per hour. The result is based on the data gathered after the break. None of the state means differ significantly from the others (Table 7).

Table 7. Analysis of Variance from ANOVA test with data from data gathered after the break. The state variable has no significant impact on the model.

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
State	4	0.021	0.005	1.511	0.204
Error	107	0.376	0.004		
C.Total	111	0.397			

Table 8. Result from fixed effect test from ANOVA test with data gathered after the break, including estimates, standard errors and confidence intervals of the mean animal visit rate for each state.

Level	No. periods	Mean	Std Error	Lower 95%	Upper 95%
B	16	0.018	0.015	-0.011	0.047
E	29	0.032	0.011	0.010	0.054
ME	27	0.058	0.011	0.035	0.080
I	24	0.053	0.012	0.029	0.077
A	16	0.015	0.015	0.012	0.070

The ANOVA test do not consider the different lengths of the periods but only the rate of animal visits per hour and the state for the site using the number of periods to calculate a mean (Table 6 and Table 8). Additionally, it does not take any other variables than state into account. Therefore, a model was fitted using standard least squares and REML, using the site label as a random effect variable. The parameter estimates thus generates a better understanding of the impact of the different states than in the ANOVA, although only one other model parameters were found significant, *Start date in number of days,* which seems to have a small positive effect on visitation rate (Table 9). The only other variable with a significant impact is *site* (as a random factor), which is also to be expected because of varying local conditions per site (Table 10). There is no significant effect of the type of *state* ($F_{4,4}$ = 0.767, P > 0.5; Table 11).

Table 9. Parameter estimates from standard least squares with REML and with period duration as weight. Only data gathered after the break was included. The start date of the period was the only variable with a significant impact on the model (in red), with a positive effect on the animal visit rate.

Term	Estimate	tRatio	Prob>|t|
Intercept	-0.022	-0.63	0.530
B	0.002	0.17	0.869
E	-0.008	-1.04	0.302
ME	0.001		
I	0.012	1.55	0.122
A	-0.006	-0.67	0.502
Distance to forest	-3.664e-5	-0.72	0.482
Nr of dog visits per day	0.001	0.48	0.635
Nr of human visits per day	4.813e-4	0.28	0.798
Start date in nr of days	0.002	2.04	0.044*

Table 10. REML variance components estimates from standard least squares with REML and with period duration as weight. Only data gathered after the break was included. The site variable had a significant impact on the model (in red).

Random Effect	Var Ratio	Wald p-Value	Pct of Total
Site	0.18	0.0277*	15.334
Residual			84.666
Total			100.000

Table 11. Fixed Effect Tests from standard least squares with REML and with period duration as weight. Only data gathered after the break was included. The start date of the period was the only variable with a significant impact on the model (in red).

Source	Nparm	DF	DFDen	F Ratio	Prob > F
State	4	4	94.41	0.767	0.549
Nr of dog visits per day	1	1	100.1	0.227	0.635
Nr of human visits per day	1	1	101	0.066	0.798
Distance to forest	1	1	17.38	0.515	0.482
Start date in nr of days	1	1	100	4.165	0.044*

4. Discussion

The *site* and *start time* of the experiment were the only variables demonstrating a significant correlation with visitation rates. In contrast, neither the display of human voices, the presence of humans or dogs, nor the distance to the forest had any significant or additive effect on visitation rates. These findings suggest that mainly other factors than the presence of human voices affect the presence of wildlife at the farms. With the increase in visitations over time it is possible that a general change in food availability within the study area had a higher impact on visitation rates than the scaring device.

Seasonal variation in rain, type of crops and crop stages might all have an effect on the attraction of wildlife to the farms. For example, most farmers harvest their maize during the break in the data collection or just after the break, meaning that the least crops were available at the farms immediately after the break. After the harvest a lot of bean sprouts were planted and these had started to grow at the end of the study, but not yet producing beans, providing food for the wildlife that might be interested in the leaves of the plant. Mangos were in season during the beginning of the study, but there were little alternative crops available in the farms. However, later during the study, avocados came into season as well which might have attracted wildlife to the farms.

The interviews with the farmers in Njukiri determined primates were causing the biggest problems in the farms. As early as 1998 was a study conducted in Uganda to predict the crop damage patterns caused by wildlife (Naughton-Treves 1998). In that study, five species accounted for 85% of the crop damage and one of them was the olive baboon. Primates in total accounted for 71% of the recorded damage events in the study. Primates are often cited as the species that causes most crop damage (Evers et al. 2022, Adedoyin et al. 2018). Monkeys are particularly challenging crop pests since they are intelligent and quick learners (Springer, 2020). According to Springer (2020), monkeys are problematic since they quickly learn deterrent methods, can carry multiple food items to safety, attack people and dogs if cornered, and evaluate food by tasting, meaning that they destroy more crops than they eat. This is similar to the problems the farmers experienced in Njukiri and in line with the results of the study.

Sound signals are supposed to induce natural reactions since they are warnings of danger and threats to survival. The sounds are used to enhance the perception of risk of foraging in an area (Gilsdorf et al. 2002). Bio-acoustic repellants use this idea by playing natural sounds like the roar of a predator or a distress call of an animal to trigger a response such as fleeing the area (Evers *et al.* 2022). While sound has worked as an efficient deterrent in other studies and on other species (Babińska-Werka et al. 2015, Thuppil & Coss 2016, Bhardwaj et al. 2022, Widen et al. 2022) and it is possible that other types of sound could have had a larger impact on the presence of wildlife (Seyfarth *et al.* 1980, Evers *et al.* 2022), the display of human voices did not have an effect as a deterrent on monkeys in this study.

It is possible that the sound of other natural predators, like leopards, could be more efficient, as was used by Evers et al. (2022). However, since there are few, if any, natural predators in Njukiri forest, the primates might not exhibit a fear response to such sounds, but it is also possible that they could recognize and react to the sound of predators even without such prior experience. Another option is to use a recorded warning call from the primates themselves (Seyfarth et al. 1980), but then the primates might respond differently depending on the type of call, for example hiding in the bushes at the warning call for eagle, or climbing a tree at the warning call for a leopard. Furthermore, warning calls from one species might not work for other species of primates. For this reason, a mix of sounds could be more effective. Babińska-Werka et al. (2015) used a potpourri of natural sounds from a range of animal species to scare animals from an area by a railroad track when a train passed. Some examples of sounds used are the warning call of a jay, the barking of a dog and a brown hare attacked by a predator. When the sound signal was emitted, animals escaped from the area more often and they reacted faster to oncoming trains, compared to when the sound was not played.

Babińska-Werka et al. (2015) did not find evidence that the animals habituated to the sound stimuli. However, their study differed from this study in the way that the acoustic signals were followed by an actual threat. Babińska-Werka et al. (2015) compared their study with a study carried out at supplementary feeding stations, where the animals instead quickly became habituated to the stimuli of the same type of natural sounds since no direct threat materialized and the animals reacted less and less over time. The study with supplementary feeding stations is more similar to this study, and quick habituation to the sounds are therefore likely due to the lack of a "real threat" after the sound display. Bhardwaj et al. (2022) induced fear in moose by using different sound stimuli and argued that the reason why males were less reactive to the acoustic stimuli was that the experiments were conducted outside of the hunting season and that "expenditure of energy towards avoiding the sites was not warranted if the threat was not true". There could be a similar case in this study that the animals are accustomed to human noise and wait for when the humans are not visible to raid.

Long random pauses between sounds were included in the sound file (0.5 min to 40 min). Since animals are used to people coming and going on the farm, and the animals take their chance foraging at the farms while people are gone, it is possible that the sound would have had an increased effect had it contained shorter breaks even at the risk of earlier habituation. However, it is also possible that the animals would take advantage of the shorter breaks to forage as well. Since the farms are very small and most farmers live on their farms, the crops are usually not left unattended for long periods of times and the wildlife are quick to escape out of reach when discovered. Monkeys can wait for many hours for an opportunity to raid a farm, keeping watch from the trees and forest edge where they feel relatively safe (Springer 2020). They may therefore not consider the speaker as a threat after assessing the situation.

The speakers were not motion triggered. With motion triggered sounds, it would have been possible to see how the animals reacted to the acoustic cue: whether the sounds triggered a fear response, and if they felt disturbed enough to leave the sites. This would also be interesting for further commercial implications but motion triggered devices have also yielded varying results in deterrent methods and require more evaluation (Bhardwaj *et al.* 2022; Ward et al. 2008; Hildreth et al. 2013; Thuppil & Coss 2016). Ward *et al.* (2008) used ultrasonic devices on badgers but found that the badgers consumed more bait when the device was active. Hildreth *et al.* 2013 scared deer using the sound of a deer in distress, and Thuppil & Coss (2016) mitigated crop-raiding by elephants using felid sounds and human shouts. Today multiple commercial options are available for deterring wildlife but lack scientific evaluation.

The results provided no evidence that the presence of humans or dogs affected the number of wildlife visitations. Even though the farmers chased away the wildlife, the farmers still had problems with the primates that would keep watch in the trees until the farmers left the site. Hence, the primates might have been habituated to the human shouts prior to the study and learned to cope with human disturbances. Since no true threat followed the acoustic stimuli or in general when the farmers chased away the wildlife.

Naughton-Treves (1998) mention other studies observing animals awaiting the departure of farmers to raid the crops. A study in South Africa examined baboons that had started to raid within urban areas (Fehlmann et al. 2017). Fehlmann *et al.* (2017) concluded that despite a high number of raids the baboons spent the biggest part of their time in close vicinity to the urban areas, but only did quick, high activity visitations lasting an average of 11 minutes (Fehlmann et al. 2017). The baboons that raided urban areas spent approximately 9.5% ± 0.8% of their time budget foraging while other baboons in Africa spent between 20.3% and 59.3% of their time foraging. Relating the result from Fehlmann et al. (2017) to this study some primates seem intelligent enough to evaluate the risks and do quick raids avoiding human presence. It also seems to be worth the risk to raid the farms compared to foraging outside the farms. A deterrence system playing noise at random intervals might therefore not work as an efficient deterrent for primates.

The reaction to the sound stimuli could also be related to the amount of cover the animals can retreat to, meaning that even though the animals hear what they believe to be a human presence, they may still feel safe with the general forest cover and trees surrounding the farms. According to Naughton-Treves (1998) olive baboons and vervet monkeys seemed to be one of the species that were able to best exploit the edges between forest and agriculture. There was a negative correlation between sight distance and crop raiding by the monkeys meaning that more bushes and trees correlated with more crop damage. Monkeys moving in the arboreal layers might feel safer with more vegetation and therefore not perceive the sounds of humans in this study as a sufficiently high risk to react to it and avoid the bait station.

On a bigger scale Naughton-Treves (1998) identified that the most damage occurred closest to the forest and most significant crop damage was concentrated at farms laying within 200 m from the forest edge. The study also concluded that the best way to protect your farm was to have a neighbor between your farm and the forest and farmers with farms smaller than 1 ha were the most vulnerable. Most farms around Njukiri were approximately this size or smaller, and with small farms the loss of crops has a relatively bigger impact for the farmer. A significant correlation between wildlife visits and distance to forest was not found in this study (Table 9, Table 11). This could be due to that this study did not differentiate between species and it is for example possible that less primate visitations occurred at sites placed further away from the forest. The study also only had sites within 550 m from the forest edge with most sites located close to the forest edge meaning that the scale might have been too small to identify a significant effect of distance (Table 4, Figure 5, Table 9).

Behavior can be plastic and change during different times of the year (Bhardwaj et al. 2022), so it is possible that the wildlife in this study also reacts differently during different seasons which means that this study might have gotten different results in another habitat or a different season. It is impossible to know if the animals perceived the sound the way we intended, or if there were external influences that affected the response of the animals. Naughton-Treves (1998) concluded that the raiding frequency on maize peaked eight weeks after the onset of rain. This could perhaps explain the small positive trend related to *start time.*

In addition, there are statistical limitations in the use of the standard least square model in this study to evaluate the effect of the deterrent (Table 9, Table 10 & Table 11). The model assumes normally distributed residuals and independent observations (Zuur et al. 2007), assumptions that however may be flawed in this dataset, most notably since the camera was motion triggered with a time lag of 30 seconds meaning that the same animal staying for multiple minutes would be recorded multiple times. It could be better to count such a prolonged visit as one observation with a longer duration. For that, the individual animals caught on camera would have to be identified, which, however, was not possible within the scope of this project.

The current study only considered the combined visits of all wildlife species. By evaluating the data on a per-species bases, it might have been possible to evaluate whether acoustic deterrence is a valid method against some, but not all, species. However, this was not possible in this study due to time constraints. It is also possible that the observations in-between sites were not completely independent. Multiple sites had to be closer to each other than preferred (Figure 2). This allows for the possibility that even though the wildlife could not hear the speaker of other sites they might have moved from one test site to another if disturbed.

All in all, this complicated the analysis of the speakers' effect in the obtained data set. Although the results do not support the idea of noise deterrents, there are limitations in the study that could have interfered with the results. It is hence too early to discard the use of sound as a deterrent in African farms and more studies, with adjusted designs, would be recommendable. Improvements for further studies would be to have the sites placed further away from each other, to use motion triggered equipment and preferable to have speakers with longer battery life or in some other way ensure functionality. Some form of protection from theft would also be advisable. It would be interesting to examine the effect of different types of sound on wildlife to determine their effectiveness if any. Further things to improve would be to look at the species-specific effects of the deterrent method and at what time during the day most visitations occur.

4.1 Conclusion

The study explored the effect of using human sounds as a deterrent on wildlife to protect crops in farms around Njukiri forest in Embu, Kenya. In this study, the sound of humans did not appear to have had any significant effect on the animal visitation rates, nor did the occasional presence of humans and dogs. The study highlights that more research is needed to look at the effects of sound on different types of wildlife.

4.2 Management implications

When considering future management, it is important to consider the logistics and practicality behind the management methods. This study did not find human sounds a sufficient method of scaring away the wildlife for the particular species found in Njukiri forest including the olive baboon, vervet monkey and syke's monkey. If future studies would suggest sound deterrence as an efficient measure for the farmers, the method needs to be able to deter wildlife from an entire farm. Furthermore, the deterrence means have to be distributed equally, so as not just scare the wildlife between neighbors. With small farm sizes, it is also important to consider the sounds' disturbance of the farmers themselves. Considering the small economical margins of the farmers, the deterrence method needs to be feasible with respect to both affordability, a lack of electricity and risk of theft. Combining and switching between different deterrent methods might be a good option to hinder habituation. Protected wildlife poses a potentially more difficult problem, since they might not have many natural predators and do not fear humans to a large extent. From a management perspective, it would be relevant to examine why the wildlife leaves the forest: is there a food shortage, or are the farmers crops just seen as accessible? Naughton-Treves study (1998) concluded that peaks in banana consumption was unrelated to rainfall or maize raiding but associated with forest fruit shortages. Conservation of fruit trees in the forest might therefore help limit the crop damage.

It is also relevant to question how big the crop losses actually are. It is easy to subconsciously exaggerate damages or perceive losses as bigger than they are in reality. In Naughton-Treves study (1998), farmers within 500 m from a forest in Uganda lost 4-7 % of the harvest, but although most damage was caused around a narrow band around the forest, risk perception among the farmers had been amplified by the legal prohibitions on killing wildlife. This could be very similar to this study's case, and if the losses are not too big, it might be possible to accept the losses in exchange for some sort of compensation from the state for that type of damage. It would therefore be of major interest to actually measure the amount of losses.

5. Data Availability Statement

Observations, sound files and other data are available upon request.

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Popular science summary

Conservation conflicts are an increasing global problem with wildlife having an adverse effect on humans and vice versa. Human and wildlife co-existence depends on limiting those adverse impacts.

In Embu, Kenya around Njukiri forest farmers face the problem of wildlife from the forest consuming their crops, with primates (olive baboons, vervet monkeys and syke's monkeys) causing the biggest damages. The farmers spend both time and money scaring the wildlife with big losses to their crops. The farmers spend both time and money chasing the wildlife away but with limited effect. The farmers scare the wildlife away by using sound, movement or physical impact. For example, they may scream and chase away the animals, throw mud and stones, set up scarecrows, bang on metal to make noise, or keep dogs. When the methods do not work, some farmers might also kill the wildlife, even though it is illegal, to deter other animals. The farmers are currently not allowed any compensation for damage caused by primates. In summary, minimizing crop damage with their current applied methods is costly, time-consuming and potentially dangerous for the farmers with still a high risk of big losses of crops. It leaves the farmers in a vulnerable position with a negative perspective of wildlife while simultaneously potentially hindering future work of conservation.

This study aimed at analyzing whether acoustic deterrence in the form of human voices could be enough to limit the crop damage caused by wildlife at least temporarily. In order to make it appear that people were more present on the farms, recordings of human voices were used. For this study, mixed recordings of farmers talking and shouting at wildlife as they usually do to scare them off. If the animals perceived the human voice as a clear sign of human presence, it could reduce the time the farmers themselves need to be on site. The sounds where mixed with random length silences so the wildlife would not get used to the sound and the mixed recordings where being looped over, playing both day and night.

The experiment was conducted at 29 different sites at farms around Njukiri forest. Every study site was equipped with a bait station, a camera and a speaker. The study sites were switched between experiment (playing the recordings) and control (no sound playing) every few days.

From the study it seems like the acoustic deterrence was not sufficient to limit the presence of wildlife. The primates are used to being chased away by humans without being physically harmed, meaning they may have become accustomed to human presence, staying close and keeping watch until the humans leave before raiding the crops. It is thus possible that voices alone are not enough to scare the animals away, further studies with more data collection would help establish if human sounds can be used as a deterrent. For future studies it would be interesting to analyze different type of sounds (for example both visual and acoustic), to see if different species of animals react differently and if there is a difference in foraging durations with sound playing. It would also be interesting to investigate why the animals raid the farms: if it is due to lack of food or due to easy access to large amounts of food in the same place.

From a human perspective, but also from a conservation perspective, the loss of crops and the negative attitude towards game is a big problem. New methods are therefore needed to keep wildlife off the farms. For new deterrence methods to work for the farmers, it is also important that they are implementable in terms of affordability, usage, safety of the equipment and availability for all farmers, so that the animals are just not scared from one farm to the next.

Populärvetenskaplig sammanfattning

Det är ett ökande globalt problem med människor som har en negativ påverkan på vilda djur och djur som har en negativ påverkan på människor. En förbättrad samexistens mellan människor och vilda djur bygger på att man begränsar dessa negativa effekter. Bevarandearbete och förhindrande av viltskador är två sätt att arbeta mot detta mål.

I Embu, Kenya, i närheten av Njukiri-skogen, står bönder inför problemet att djur från skogen kommer och konsumerar deras grödor. Det är framför allt apor (anubisbabianer och två typer av markattor) som orsakar de största skadorna. Bönderna lägger både tid och pengar på att jaga bort djuren men med endast begränsad effekt. Bönderna skrämmer bort djuren genom ljud, rörelse eller fysisk påverkan. Exempelvis kan de skrika och jaga efter djuren, kasta lera och stenar, sätta upp fågelskrämmor, slå på metall för att åstadkomma ljud, eller ha hundar. När metoderna inte fungerar dödar även vissa bönder djuren, trots att det är olagligt. Bönderna får ingen ersättning av staten för skador orsakade av primater. Att minimera skador på grödorna är sammanfattningsvis kostsamt, tidskrävande och potentiellt farligt för bönderna. Det lämnar bönderna i en utsatt position, samtidigt som det skapar en negativ inställning till djurlivet vilket kan försvåra framtida bevarandearbete.

Denna studie syftade till att analysera om mänskliga röster fungerar som avskräckning för att åtminstone tillfälligt begränsa skadorna på grödor som orsakas av vilt. För att få det att verka som att människor i större utsträckning var närvarande på gårdarna användes därför inspelningar av mänskliga röster. För denna studie användes blandade inspelningar av bönder som pratade och ropade på samma sätt som de brukar för att fösa bort vilda djur. Om djuren uppfattade den mänskliga rösten som ett nog tydligt tecken på mänsklig närvaro så skulle det kunna det minska tiden som bönderna själva behöver vara på plats. Inspelningarna blandades med pauser av slumpmässig längd under dygnet så att djuren inte skulle vänja sig vid eller kunna förutsäga ljudet.

Experimentet genomfördes på 29 olika gårdar runt Njukiri-skogen. Varje studieplats var utrustad med en betesstation, en kamera och en högtalare. Uppspelning av ljudet genomfördes växelvis på olika platser för att på så sätt skapa både test- och kontrollplatser.

Resultatet antyder att den ljudbaserade avskräckningen inte var tillräcklig för att minska besök av vilda djur vid testplatserna. Aporna är vana vid att jagas bort av människor utan att ta fysisk skada, vilket betyder att de kan ha vant sig vid mänsklig närvaro, och därför hållit sig nära och övervakat tills människorna lämnar gården innan de plundrar grödorna. Det är på så sätt möjligt att endast röster inte räcker för att skrämma bort djuren, och ytterligare studier skulle behövas för att fastställa om ljudet av människor räcker som ett avskräckande medel. För framtida studier skulle det vara intressant att analysera olika typer av signaler (till exempel både visuella och akustiska) för att se om olika djuren reagerar på olika sätt, och studera om det finns en skillnad mellan olika metoder i hur länge de stannar och äter av grödorna. Det skulle också vara intressant att undersöka varför djuren besöker gårdarna: om det beror på brist på mat eller på grund av lättillgängligheten till stora mängder mat på samma ställe.

Ur ett mänskligt perspektiv, men också ur ett bevarandeperspektiv, är förlusten av grödor och den negativa inställningen till vilt ett stort problem. Nya metoder behöver därför utvecklas för att hålla djurlivet borta från gårdarna. För att nya avskräckningsmetoder ska fungera för bönderna är det viktigt att de är genomförbara vad gäller kostnad, användning, säkerhet och tillgänglighet. Om skrämselmetoderna inte fungerar för alla bönder finns risken att djuren helt enkelt går från en gård till en annan.

Acknowledgements

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Appendix 1

Table A1. Farmers' response to the question: Rank your opinion of the wildlife in the area from 1 to 6.

Response	Number of replies
Very Negative	61
Negative	12
Slightly Negative	8
Slightly Positive	3
Positive	4
Very Positive	2

Appendix 2

Table A2. Audio file content and order.

Order	Name of audio recording	Length of recording in minutes
1	Shout 6 man	0.68
2	5 silence	5
3	Shout 6 man	0.68
4	2 silence	2
5	10 silence	10
6	10 silence	10
7	Shout 8 man	0.68
8	30 silence	30
9	Talk 3 Mixed	0.68
10	0,2 silence	
11	Talk 7 Mixed	0.68
12	5 silence	5
13	Talk 3 Mixed	0.68
14	0,2 silence	0.33
15	2 silence	2
16	Shout 5 man	5
17	0,2 silence	0.33
18	5 silence	5
19	Talk 3 Mixed	0.68
20	10 silence	10
21	30 silence	30
22	Talk 8 Mixed	0.68
23	2 silence	2
24	Talk 3 Mixed	0.68
25	30 silence	30
26	Shout 7 people	0.68
27	2 silence	2
28	Shout 6 man	0.68
29	30 silence	30
30	Talk 8 Mixed	0.68
31	2 silence	2
32	Talk 7 Mixed	0.68
33	2 silence	2
34	Shout 8 man	0.68

35	30 silence	30
36	Shout 6 man	0.68
37	10 silence	10
38	Talk 1 Men	0.68
39	2 silence	2
40	Talk 3 Mixed	0.68
41	0,2 silence	0.33
42	Talk 7 Mixed	0.68
43	0,2 silence	0.33
44	Shout 5 man	0.68
45	5 silence	5
46	Shout 7 people	0.68
47	10 silence	10
48	Shout 5 man	0.68
49	30 silence	30
50	0,2 silence	0.2
51	Talk 3 Mixed	0.68
52	5 silence	5
53	Talk 8 Mixed	0.68
54	5 silence	5
55	Talk 8 Mixed	0.68
56	Shout 6 man	0.68
57	0,2 silence	0.33
58	Shout 7 people	0.68
59	2 silence	2
60	0,2 silence	0.33

Appendix 3

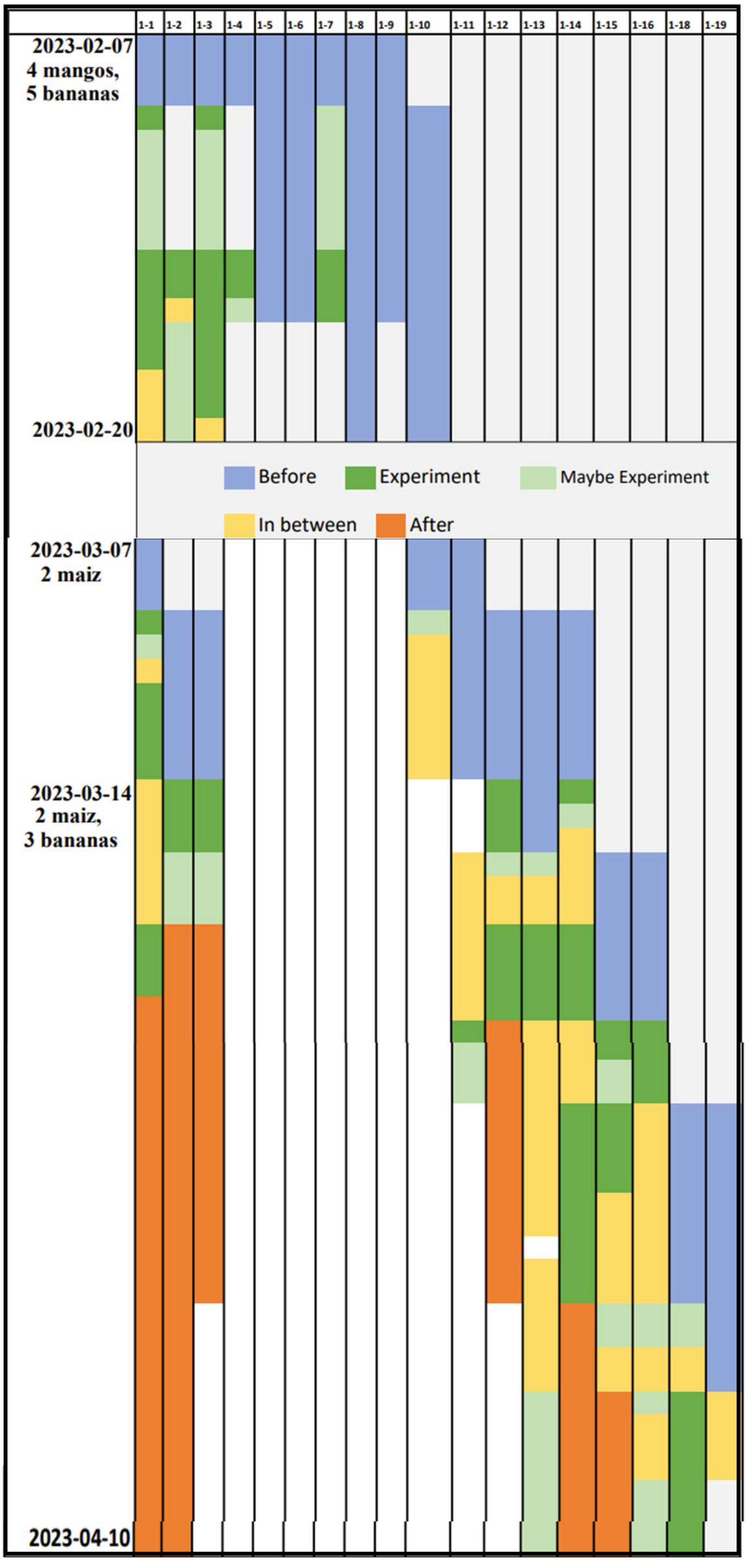

Figure A1. Simplified overview of the state over time. Showing site 1-1 to 1-19.

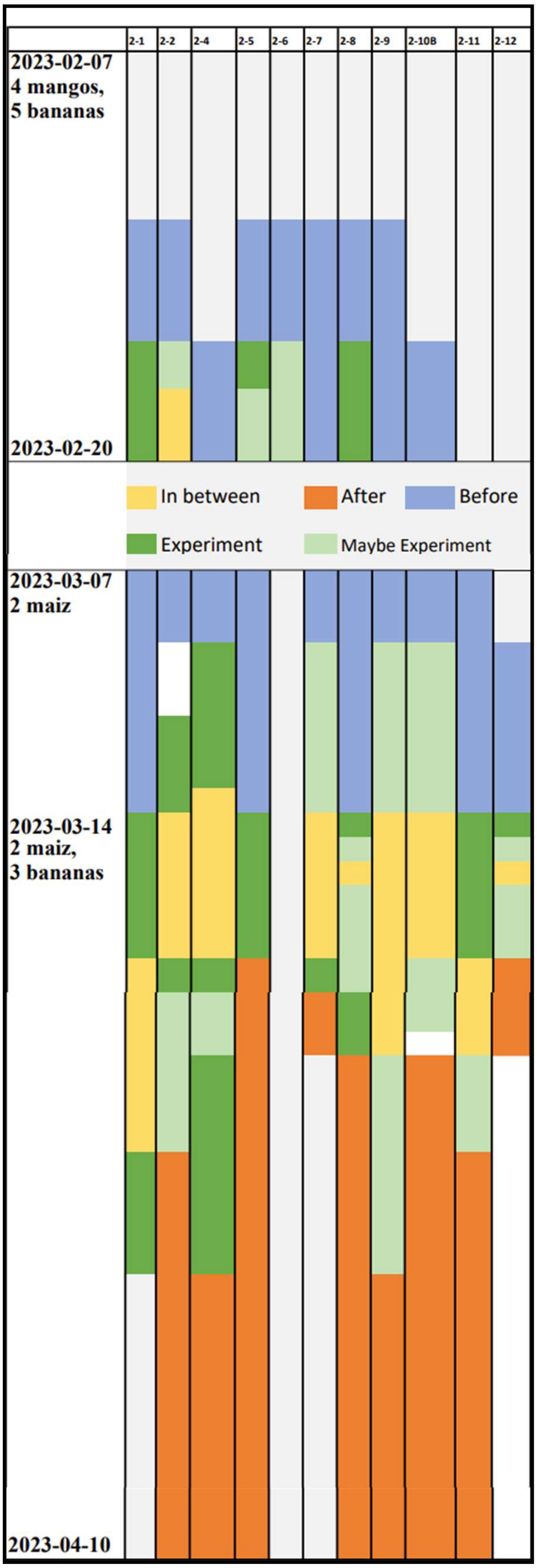

Figure A2. Simplified overview of the state over time. Showing site 2-1 to 2-12.

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