Alleviating human-elephant-conflict as naturally as possible

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Introduction

Human-elephant-conflict has increased in recent years. In Kenya alone 200 people have been killed in human-elephant-conflict over the past seven years (Duncan 2003). In various areas throughout Africa, elephants have destroyed more than 60% of crops in communal areas adjoining conservation areas (Anon 2003). In South Africa, annual aerial censuses have indicated that elephant numbers have increased within the Kruger National Park (Whyte 2001) and adjacent conservation areas. The possible destruction of woodlands by increased elephant populations is of aesthetic, economic and ecological importance to both managers and landowners who want to protect various tree species that have become typical of certain landscape types. Monitoring therefore needs to take place to evaluate the situation. In addition to these concerns, elephants have been reported to damage various structural features such as water pipes and taps within inhabited areas in or around nature reserves. Elephant impact on crops, selected tree species and/or human infrastructure has been closely associated with a combination of factors which either include the compression of elephant's range, the expansion of elephant or human populations or diminishing food and water sources associated with the dry season. As human-elephant-conflict has steadily increased so too has the need to develop a cost-effective means of deterring elephants or minimizing their impact within certain areas.

Three methods have been proposed to prevent elephant damage with preliminary results in East and South Africa indicating that the wire netting of tree stems could potentially be used as one such mitigation measure against tree loss (Gordon 2003, Henley & Henley 2004, Henley & Henley 2005a). Other ways to protect crops or particular specimens of vulnerable trees include the placement of bee hives in strategic trees as elephants are sensitive to the sound and sting of bees (Karidozo & Osborn 2005, Vollrath & Douglas-Hamilton 2005a & 2005b). The use of chilli extracts has also shown particular promise not only because *Capsicum* spp.based products are non-toxic and environmentally friendly, but specifically because elephant's advanced olfactory and memory capabilities make them suitable for adverse conditioning (Osborn & Rasmussen 1995, Osborn 1997). Numerous evaluations with chilli extracts have been completed – particularly in Zimbabwe where the objective was to protect crops belonging to rural populations that adjoin nature reserves or where elephants have caused extensive damage to crops (Osborn & Parker 2002, Osborn & Parker 2003). These evaluations have been mainly directed at a practical and cost effective means of applying capsicum oleoresin in different forms like sprays and treated ropes which are strung around crops. Research has shown the effectiveness of chilli extracts as a spray, when administered upwind of elephants and compared to traditional methods of trying to deter elephants during crop raiding. When traditional measures are utilised, there is normally an aggressive reaction from elephants, whereas in the case of aerial spraying of capsicum oleoresin, the response by the elephants was more rapid and resulted in prompt withdrawal from the crops without aggression (Osborn 2002). Capsicum oleoresin has thus far functioned as a viable short term elephant repellent.

Aims and objectives

This project ultimately aims to look at ways to develop a tolerant relationship between elephants and people in areas where the two species co-exist. To achieve this outcome two approaches will be taken. The first set of experiments will involve trials that will be conducted within a relatively short time frame on semi-habituated elephants with the intention to register a capsicum based elephant repellent in terms of Act 36 of 1947. A pilot investigation into the second approach has already started in 2004 with the wire-netting of trees at two study sites within the Association of Private Nature Reserves (APNR). These experiments will be extended to include a third study site and depending on the outcome of the first approach, chilli extracts will be applied to selected tree species to test the efficacy of this mitigation method over the medium to long term in addition to the wire netting technique. As each of these experimental trials will involve different research questions, the methodology pertaining to each approach will be discussed under separate headings.

Research questions

Firstly, trials were designed to test whether a chilli based extract works as an elephant repellent on semi-habituated elephants. Experiments were designed to address four questions which would be of importance to marketing any elephant repellent:

1. Does the chilli extract repel elephants when other choices are available and in the absence of alternative food choices?
2. At what concentration of the extract are elephants repelled?
3. How long does the treatment remain effective?
4. At what range does the product prove efficient?

Secondly, once these questions have been answered, the product will be tested in field-based experiments to determine the efficacy of the repellent and/or other methods to alleviate the impact of free ranging elephant populations on selected tree species within the APNR on the western border of the Kruger National Park (KNP). As a questionnaire survey conducted in 2003 revealed that landowners within the APNR had expressed their concern about the impact of elephants on especially *Sclerocarya birrea* (Marula) and *Acacia nigrescens* (Knob thorn) trees, experiments will focus on these species and will be designed to answer:

1. What are the medium to long-term changes in woodland structure over time?
2. What is the efficacy of the various methods used to deter elephants from damaging selected tree species?
3. Can the various mitigation methods be used in the medium to long term to ensure the aesthetic features of the landscape?
4. Can the various mitigation methods be used in the medium to long term to create localised woodland refugia that would maintain the structural diversity of the landscape and prevent biodiversity loss at a larger scale?
5. Can the various mitigation methods be used in the medium to long term to create woodland refugia which function as important seed reserves for future recolonisation of other areas?

Finally, we hope to expand the project to determine whether the mitigation methods can be extended to protect crops and various structural features such as water pipes and taps from elephant damage both within and on the border of conservation areas.

Relevance of the study

The research will address local concerns about elephant impact. The information gained from these trials will be used to advise landowners on how to protect specific trees that are of aesthetic importance to them. Providing a simple toolkit that landowners can use to protect their trees and/or infrastructure from elephant damage will ultimately change people's perceptions and make allowance for a more tolerant co-existence between the two species. Furthermore, at an ecological level, mitigation methods such as the wire-netting technique has already been used to protect the nesting sites of various tree-nesting birds such as the Southern Groundhornbill (*Bucorvus leadbeateri*) and the African Whitebacked Vulture (*Gyps africanus*) (Henley & Henley 2005b) within the APNR. Both these species are listed as vulnerable in the Red *Data Book of Birds of South Africa, Lesotho and Swaziland* (Barnes 2000).

At present, there is an active debate at national level, both within the scientific and public domains, concerning the implications of an increasing elephant population on the biodiversity and ecological processes in the KNP (Rogers 2005). If the methods prove effective in preventing tree loss in the long term, tree sanctuaries can be created according to the distribution of impact intolerant species or around particularly vulnerable species. If patches of trees sanctuaries are created at large enough spatial scales, these areas could act as valuable seed banks to populate surrounding areas (Western & Muitomo 2004). To this effect some degree of environmental manipulation may be more acceptable than large scale culling of elephants, especially if the same outcome for biodiversity conservation can be achieved (Henley 2005).

Dispersal of elephants or the expansion of their range will depend on whether nutritional, social and/or safety benefits are available to them in new areas. In East Africa elephants were found not to use their range homogenously but linked home sectors where they spent most of their time with travel corridors. Travel corridors outside protected areas were crossed under the cover of darkness and the travelling speeds along these corridors were much faster than in other areas (Douglas-Hamilton *et al*. 2005). Travel corridors would for instance provide access to nutritional benefits available in other areas. The Gourma elephants of Mali migrate in a counter clockwise circle with a 450km circumference in relation to the seasonal availability of water and food resources (Barnes *et al.* 2004) while in Namibia, elephants make use of particular segments of their home range in response to the seasonal fruiting of trees (K. Leggett pers.comm.). Elephants are therefore capable of adaptive behaviour in response to spatio-temporal variability in habitat conditions (Owen-Smith 2005).

Former recolonisation rates in the KNP have averaged 5-7km per year (as cited by Cumming *et al.* 2005). The establishment of the Great Limpopo Transfrontier Park with Mozambique in particular, will allow considerable opportunities for elephants to either disperse or to expand their range. Mozambique has adopted a National Strategy for the Management of Elephants according to which they aim to increase their elephant population by 20% by 2010 (Blanc *et al*. 2003). Recent reports have indicated voluntary movements of elephants into Limpopo National Park despite the more than 20 000 people which still occupy the area. Although the potential for human-elephant conflict exists, especially in areas where people are distributed in close proximity to water sources, results from East Africa indicate that because of elephant's spatial awareness of safe areas, they may not occupy areas where human densities exceed 15/km^2 (Hoare & Du Toit 1999), but they could potentially still use areas inhabited by humans as vital travel corridors. If the inhabitants of such areas either apply compatible land-use practises or make use of efficient mitigation methods against elephant impact, travel corridors need not represent areas of conflict between the two species. This research therefore ultimately stands to offer solutions to alleviating human-elephant conflict along these critical corridors that are necessary to encourage dispersal of elephants from one conservation area to the next. Enabling elephants to vary their habitat use in both space and time by providing opportunities for large scale movements would alleviate the severity of local impacts. Irrespective of the motivating forces behind large scale movements, results indicate that it would be possible to induce a range of elephant densities by keeping open crucial corridors identified by high-resolution radio tracking and the application of effective techniques aimed at alleviating human-elephant conflict and thereby spread elephant impact between different segments of their range (Douglas-Hamilton *et al*. 2005, Van Aarde *et al*. 2005).

Methods (first approach)

Experimental design to test whether a chilli based extract works as an elephant repellent on semi-habituated elephants

Three study sites with semi-habituated elephants will be used during the trials and will consequently be referred to as study site A-C. An initial test trial was conducted at study site A in which semi-habituated elephants were given the command to pick up panels made from different substances (wood, plastic and metal piping) treated with varying concentrations of ChileGuard (Global Source Advantage, Nature's Repellent). It soon became apparent that the elephants' reaction to the repellent was confounded by their willingness to obey the commands given by their trainers. In subsequent trials it was decided to allow individual elephants free choice to 'interact' with treated food items. The criteria being to eliminate human commands and the influence of other elephants as far as possible.

Corn cobs (*Zea mays*) were cut into similar sized circular wedges. The wedges were small enough so as to not enable the elephant to take one bite and drop the rest i.e. the choice must be 'all or nothing', thereby enabling easier interpretation of the results. As the tests have important implications for crop raiding elephants, corn cobs were chosen as the sought after food item. Upon experimentation at study site B it was decided to replace corn cobs with orange (*Citrus* spp.) halves as the cobs proved to be unattractive to the elephants. Each of the orange halves was mounted on a wooden skewer to secure it into the ground of the experimental site so that any subsequent handling by the study animal would be clearly visible for filming purposes. While preparing the orange halves, plastic gloves were worn at all times to ensure that the food item, whether treated or untreated had a neutral scent with regards to humans. Preferably, five elephants will be used during each of the trials and at each of the three study sites. The labelled orange halves were secured in the ground according to the following design:

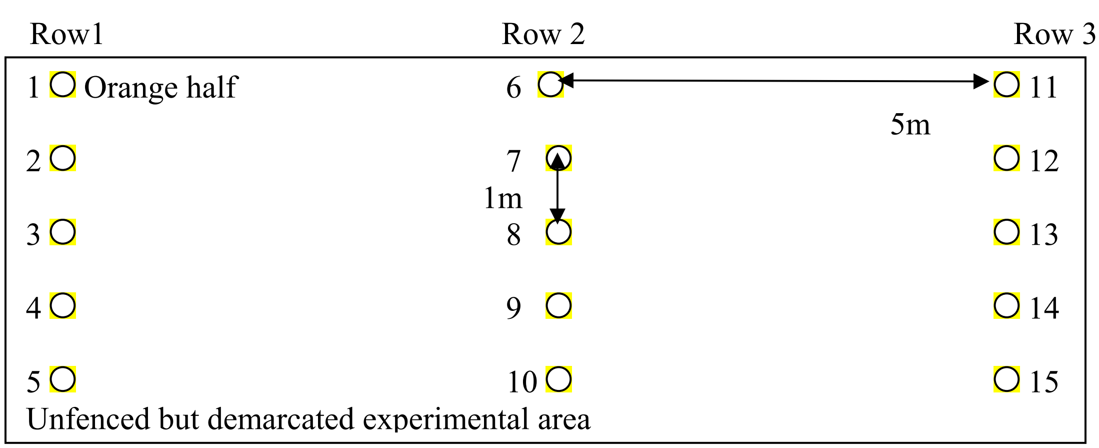

Figure 1. Experimental design for trials with semi-habituated elephants.

An individual study animal was released from its holding pen and was directed towards the experimental area and thereafter left to interact with the food items on its own accord. A human observer was stationed some distance away from the area and collected video footage on each of the five elephants' reactions. Another observer called out the sequence of the elephant's movements as well as it's behaviour towards the food items that it approached to a third observer who recorded the data onto a grid based datasheet which corresponded to the experimental lay out of the food items (Appendix 1-5). As an elephant approached a food item, it's behaviour was recorded as having 'ignored', 'inspected', 'handled' or 'consumed' a food item. Each experimental setup was repeated for each of the elephants.

Trial 1:

Orange halves were laid out according to the abovementioned design for each of five different study animals (Appendix 1). All the orange halves were handled with gloves but were not treated in any way. Each of the five different elephants was allowed to inspect, handle or consume the untreated oranges for an undetermined length of time until all the oranges had been visited.

Questions answered:

1) Are the orange halves attractive enough to lure elephants willingly to partake in the experiment?
2) What is the average testing time for an elephant to inspect/consume all 15 orange halves?

Trial 2:

Orange halves were treated as follows:

- Six were not be treated in any way
- Three were treated with 5% water miscible ChileGuard
- Three were treated with 5% oil soluble ChileGuard
- Three were treated with 5% water soluble ChileGuard mixed with plant sticker.

The orange halves were randomly placed according to the design presented in Appendix 2. The same random design was repeated for each of the five study animals. Each of the five different elephants were allowed to consume or handle any of the orange halves for a predetermined time (refer to 'Trial 1' above) within the experimental area.

Question answered

1) Does the repellent work when there is a choice to avoid it i.e. are the elephants only eating the untreated oranges when they have a choice to do so?
2) Does the solvent with which the ChileGuard is mixed influence their level of avoidance?

Trial 3:

Orange halves were treated as follows:

- Five were treated with 5% water miscible ChileGuard
- Five were treated with 5% oil soluble ChileGuard
- Five were treated with 5% water soluble Chile Guard mixed with plant sticker.

The orange halves were randomly placed according to the design presented in Appendix 3. The same random design was repeated for each of the five study animals. Each of the five different elephants were allowed to consume or handle any of the orange halves for a predetermined time (refer to 'Trial 1' above) within the experimental area.

Question answered

1) Does the repellent work when there is no choice to avoid it i.e. will the elephants eat the treated oranges when no untreated oranges are available?
2) Does the solvent with which the ChileGuard is mixed influence their level of repulsion?

Trial 4:

Orange halves were treated as follows:

- One orange half was treated with water (the solvent for the water based extract)
  One orange half was treated with sunflower oil (the solvent for oil-based extract)
  One orange half was treated with water and plant sticker (the solvent for water based extract to make it more durable)
- One orange half was treated with 1.5 % of the water based Chilli extract
  One orange half was treated with 1.5% of the oil-based Chilli extract
  One orange half was treated with 1.5% of the water based extract mixed with plant sticker
- One orange half was treated with 3% of the water based Chilli extract
  One orange half was treated with 3% of the oil-based Chilli extract
  One orange half was treated with 3% of the water based extract mixed with plant sticker
- One orange half was treated with 4.5% of the water based Chilli extract
  One orange half was treated with 4.5% of the oil-based Chilli extract
  One orange half was treated with 4.5% of the water based extract mixed with plant sticker
- One orange half was treated with 5% of the water based Chilli extract
  One orange half was treated with 5% of the oil-based Chilli extract
  One orange half was treated with 5% of the water based extract mixed with plant sticker

The orange halves were randomly placed according to the design presented in Appendix 4. The same random design was repeated for each of the five study animals. Each of the five different elephants were allowed to consume or handle any of the orange halves for a predetermined time (refer to 'Trial 1' above) within the experimental area.

<u>Questions answered</u>

1) At what concentration of Chilli extract are elephants repelled?
2) Does the solvent with which the ChileGuard is mixed influence the concentration at which the repellent become effective?

Trial 5:

As fresh oranges could not be used in the durability experiment, another food item had to be used which would not decay over a period of a month but which would nevertheless be attractive to the elephants. Thus, a quantity of approximately 800 grams of horse cubes were placed in an aluminium foil tray, and then a 5 % solution (either oil soluble, water soluble or water soluble plus plant sticker) was painted onto the cubes. For each treatment of cubes, a quantity of 100 mℓ of solution was prepared to treat the 800 g of horse pellets in each aluminium trays. In addition to the treated cubes, a quantity of untreated cubes was also placed in trays to function as controls. All horse cubes used during this trial were then exposed to the elements five weeks prior to experimentation so that the age of the treated food items could be ruled out as a factor contributing to its acceptance or avoidance by the elephants. Daily weather data was obtained during this 5 week period at a weather station closest to the location at which the pellets were being treated for the trial. The treated and untreated cubes were then packaged in paper towels. The package was secured with some cotton string – where it was assumed that the paper and the cotton would have no objectionable odours that could complicate this trial. The packaged horse cubes contained them in a form where the elephants could readily pick them up and consume the majority of them in a feeding event that would come close to the 'all or nothing' option that treated orange halves had offered during other trials.

To answer the questions associated with ‘Trial 1’ using horse pellets instead, approximately 800g of untreated horse pellets were placed in 15 individual paper towel packages according to the experimental design depicted in Figure 1.

Once the attractiveness and the handling time of this food item had been determined according to the methods used in ‘Trial 1’, approximately 800g of horse cubes were treated as follows:

- 800g of horse cubes were treated with 5% of the water based Chilli extract applied 1 week before experimentation
  800g of horse cubes were treated with 5% of the oil-based Chilli extract applied 1 week before experimentation
  800g of horse cubes were treated with 5% of the water based Chilli extract mixed with plant sticker applied 1 week before experimentation
- 800g of horse cubes were treated with 5% of the water based Chilli extract applied 2 weeks before experimentation
  800g of horse cubes were treated with 5% of the oil-based Chilli extract applied 2 weeks before experimentation
  800g of horse cubes were treated with 5% of the water based Chilli extract mixed with plant sticker applied 2 weeks before experimentation
- 800g of horse cubes were treated with 5% of the water based Chilli extract applied 3 weeks before experimentation
  800g of horse cubes were treated with 5% of the oil-based Chilli extract applied 3 weeks before experimentation
  800g of horse cubes were treated with 5% of the water based Chilli extract mixed with plant sticker applied 3 weeks before experimentation
- 800g of horse cubes were treated with 5% of the water based Chilli extract applied 4 weeks before experimentation
  800g of horse cubes were treated with 5% of the oil-based Chilli extract applied 4 weeks before experimentation
  800g of horse cubes were treated with 5% of the water based Chilli extract mixed with plant sticker applied 4 weeks before experimentation
- 800g of horse cubes were treated with 5% of the water based Chilli extract applied 5 weeks before experimentation
  800g of horse cubes were treated with 5% of the oil-based Chilli extract applied 5 weeks before experimentation
  800g of horse cubes were treated with 5% of the water based Chilli extract mixed with plant sticker applied 5 weeks before experimentation

The 800g clusters of horse cubes were randomly placed according to the design presented in Appendix 5. The same random design was repeated for each of the five study animals. Each of the five different elephants was allowed to consume or handle any of the clusters of horse cubes for a predetermined time established prior to experimentation within the experimental area.

<u>Questions answered</u>

1) For how long after treatment is the minimum concentration at which repulsion first occurred effective?
2) Which of the solvents proved to be the most durable and for what period of time after the application of the treatment?

<u>Trial 6:</u>

Fifteen untreated orange halves were laid out according to the original experimental design (Figure 1).

- The first row of untreated orange halves were placed on wooden skewers and surrounded with a rope soaked in 5% of the oil-based Chilli extract. The rope was placed at an equal distance of 50cm from all of the untreated orange halves in row 1 and was suspended from metal fencing pegs at a height of approximately 1m above the ground.
- The second row of untreated orange halves were placed on wooden skewers and surrounded with a rope soaked in 5% of the oil-based. The rope was placed at an equal distance of 1.5m from all the untreated orange halves in row 2 and was suspended from metal fencing pegs at a height of approximately 1m above the ground.
- The third row of untreated orange halves were placed on wooden skewers and surrounded with a rope soaked in 5% of the oil-based. The rope was placed at an equal distance of 3m from all the untreated orange halves in row 3 and was suspended at a height of approximately 1m above the ground.

Each of the five different elephants was allowed to consume or handle any of the untreated orange halves within the experimental area. On completion of the testing time, the study animal was removed and all the orange halves consumed, handled (removed from their sticks) or inspected (footprints or trunk marks around barrier ropes) were recorded on a grid based datasheet which corresponds to the way in which they were laid out (Appendix 6). Video footage of how the elephants navigated around the treated ropes to reach the untreated orange halves, was carefully documented and quantified as ‘smelt’, ‘avoided by stretching to reach the food item’ or ‘totally avoided by not touching the food item’. The same experimental design was repeated for each of the five study animals.

Questions answered

1) At what spatial range does the product prove to be effective?
2) Are elephants prepared to break through chilli barriers to obtain what they are looking for?

Results and discussion

The results presented here are preliminary as they reflect the completion of trails 1-6 at study site B. The same trials will be repeated at study site A and C. For logistical reasons, trials 1-4 were completed on one day while trials 5-6 were completed on another day two months after the initial experiment. One of the elephant’s data were excluded from the results as this animal was only available on the first experimental day but not on the second.

Both orange halves and horse cubes proved to be effective in luring the elephants to willingly part take in the trials. Untreated oranges were more attractive than treated oranges when the elephants were faced with a choice to consume treated versus untreated oranges (Table 1, trial 2). When the elephants weren’t presented with a choice they avoided the treated oranges, irrespective of the type of solvent that was used during the trial (Table 1, trial 3). Controls for water miscible repellent mixed with plant sticker and for oil miscible repellent proved to be more attractive than treated oranges, irrespective of the concentration at which the repellent was being applied. Oranges with 3% water miscible repellent was accepted as frequently as the control which was treated with water only (Table 1, trial 4). On two occasions 5% oil soluble ChileGaurd, which had been applied to horse cubes 2-3 weeks prior to experimentation, was accepted by one of the four study animals (Table 1, trial 5). Further experimentation will determine whether the outcome of trials 4-5 are a consequence of the small number of study animals used during the experiment. The treated rope did not repel elephants from taking untreated oranges out of the enclosed area. Thus, it is unlikely that a treated perimeter will prevent elephants from accessing a food resource that is attractive to them (Table 1, trial 6).

Table 1: Preliminary results of trials 1-6 conducted at study site B. The acceptance values for trials 1-3 and trial 6 were determined by calculating the proportion of food items that were consumed across study animals. The acceptance values for Trials 4-5 were determined by calculating the proportion of study animals that consumed a particular food item.

Trial	Treatment	Acceptance (%)
1	Untreated oranges (n=60)	100
2	Untreated oranges (n=24)	71
	5% water miscible ChileGuard (n=12)	0
	5% water soluble ChileGuard with plant sticker (n=12)	25
	5% oil soluble ChileGuard (n=12)	0
3	5% water miscible ChileGuard (n=20)	0
	5% water soluble ChileGuard with plant sticker (n=20)	0
	5% oil soluble ChileGuard (n=20)	0
4	Water only (n=4)	50
	1.5 % water miscible ChileGuard (n=4)	0
	3 % water miscible ChileGuard (n=4)	50
	4.5 % water miscible ChileGuard (n=4)	0
	5 % water miscible ChileGuard (n=4)	0
	Water with plant sticker (n=4)	100
	1.5 % water miscible ChileGuard with plant sticker (n=4)	0
	3 % water miscible ChileGuard with plant sticker (n=4)	25
	4.5 % water miscible ChileGuard with plant sticker (n=4)	0
	5 % water miscible ChileGuard with plant sticker (n=4)	0
	Oil only (n=4)	25
	1.5 % oil miscible ChileGuard (n=4)	0
	3 % oil miscible ChileGuard (n=4)	0
	4.5 % oil miscible ChileGuard (n=4)	0
	5 % oil miscible ChileGuard (n=4)	0
5	5 % water miscible ChileGuard, 1 week old (n=4)	0
	5 % water miscible ChileGuard, 2 week old (n=4)	0
	5 % water miscible ChileGuard, 3 week old (n=4)	0
	5 % water miscible ChileGuard, 4 week old (n=4)	0
	5 % water miscible ChileGuard, 5 week old (n=4)	0
	5 % water miscible ChileGuard with plant sticker, 1 week old (n=4)	0
	5 % water miscible ChileGuard with plant sticker, 2 week old (n=4)	0
	5 % water miscible ChileGuard with plant sticker, 3 week old (n=4)	0
	5 % water miscible ChileGuard with plant sticker, 4 week old (n=4)	0
	5 % water miscible ChileGuard with plant sticker, 5 week old (n=4)	0
	5 % water miscible ChileGuard with plant sticker, 5 week old (n=4)	0
	5 % oil miscible ChileGuard, 1 week old (n=4)	0
	5 % oil miscible ChileGuard, 2 week old (n=4)	25
	5 % oil miscible ChileGuard, 3 week old (n=4)	25
	5 % oil miscible ChileGuard, 4 week old (n=4)	0
	5 % oil miscible ChileGuard, 5 week old (n=4)	0
6	Untreated oranges in row 1 (n =20)	100
	Untreated oranges in row 2 (n=20)	100
	Untreated oranges in row 3 (n=20)	100

Methods (second approach)

Elephant impact on selected tree species over time and the application of methods to protect trees and reduce human-elephant-conflict

To monitor the impact of elephants on selected trees species over the long-term and also to experiment with the various methods of alleviating elephant impact, two study sites were established within the APNR in 2004 where the wire netting technique was applied as mitigation method. Recently a third study site has been proposed from which elephants have been excluded and subsequent movement into the area will be monitored (spoor plots on the gravel road around the perimeter of the property) once the fences surrounding this study site are removed. At the research sites there will be areas where *Sclerocarya birrea* (Marula) and *Acacia nigrescens* (Knob thorn) trees are untreated (controls) and where they have been treated in some way (wire netting, painted with chilli extract or a combination of treatments depending on the study site). At the third study site, treatment of trees will be applied in three blocks (wire netting only, chilli extract only and wire netting and chilli combined), each treatment block will be separated by control blocks where no treatment has been applied (refer to Figure 2).

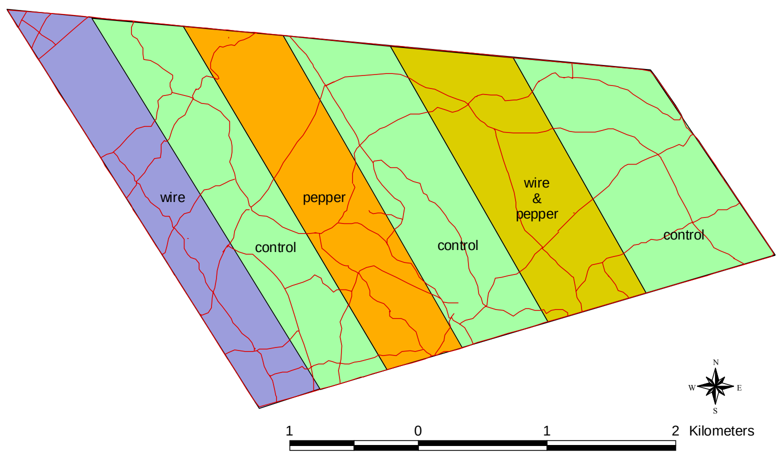

Figure 2. Joubertshoop property which is to be incorporated into the Klaserie Private Nature Reserve. Wire-netting, chilli extract, and a combination of wire netting and chilli extract treatment blocks (from left to right) will be interspersed with control areas.

Wire netting and chilli extract will be applied in specified blocks prior to the fences being removed and will be reapplied at a frequency determined during the durability experiment (refer to 'First approach' day 5). The chilli extract will be applied at a predetermined concentration, using the solvent that proved most durable during previous experimentation (refer to 'First approach' day 4). Treatment with beehives has not been established but may be in place in certain areas by 2007. Transects will be laid out in each of the experimental blocks. Each of the transects will be mirrored on the adjacent property which has been open to elephant impact for a number of years. The trees on the adjacent transect will however not be treated in any way and will provide data on the accumulative impact of elephants on *Acacia nigrescens* and *Sclerocarya birrea* trees. The controls between the experimental blocks will provide information on the efficacy of the various treatment methods and also the changes in impact over time. All trees (both the controls and the treated trees) that form part of the transect will be labelled with small metal tags so that they can be revisited on a biannual basis (wet and dry season surveys). Transects will generally be 1km in length and 200m in width (100m either side of the midline). The following information will be recorded onto datasheets:

1) The label on the indicator pin (Ref #)

2) The <u>tree species</u>. If the tree is a *Sclerocarya birrea* tree, the <u>sex</u> (**M**-male, **F**-female) will be determined by looking for fruit kernels on the ground
3) The tree <u>location</u> according to its GPS co-ordinates (decimals degrees h dd. ddd).
4) Stem <u>diameter</u> at breast height (**DBH**) in cm
5) Estimate of the <u>height</u> of the tree canopy as <1m, 1-2m, 2-3m, 3-5m or >5m
6) The <u>impact type</u> as: **BS**-bark stripping
   BBA-Primary branch breaking to access smaller plant parts
   MS-Main stem breakage as the main stem has been snapped off
   UR-Uprooting
7) The <u>extent of the impact</u> for each of the different impact types according to the following classes:
   Class **1**: none
   Class **2**: < 1%
   Class **3**: 1-5%
   Class **4**: 5-10%
   Class **5**: 10-25%
   Class **6**: 25-50%
   Class **7**: 50-75%
   Class **8**: 75-90%
   Class **9**: 90-99%
   Class **10**: 100%

- Bark stripping (**BS**) is estimated according to the above mentioned impact classes by looking at the proportion of the circumference stripped of bark. A tree that has been totally ring-barked will fall within class 10 for example.
- Primary branch breaking to access smaller plant parts (**BBA**) is estimated according to the proportion of primary branches that have been broken. If for example a tree only has two primary branches and one of these have been broken then the impact category for BBA will be class 6 or 7, depending on whether the broken branch was the smaller or large of the two branches.
- If the tree was uprooted (**UR**) or the main stem broken (**MS**) within the past season and the tree was still alive then the impact is placed into the 90-99% (class 9) category. If the woody plant has subsequently died then the impact is scored at 100% (class 10).

9) <u>Tusk entry height</u>: These measurements are only applicable where bark stripping has occurred and scars are visible were the tusk entered the tree. Measure the height above the ground of the tusk entry point.
8) <u>Age of impact</u>: Recent or current season impact will be distinguished from old impact by the pink fleshy colour of the exposed stem in the former
   * Recent (within the past month)
   * Within the past dry/wet season
   * Within the past year (wet and dry cycle)
   * More than a year old
9) <u>Treatment</u> applied-none, wire-netting only, chilli treatment only, wire-netting and chilli treatment, beehive protection, natural protection by other plants
10) Additional <u>notes</u>: any healing that has subsequently occurred (especially for old marula bark-stripping events) or the condition of the treatment method and whether it has deteriorated (wire rusted or broken, chilli extract washed or scraped off, beehives inactive)

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Appendix 1 (Trial 1)

Experimental design to determine whether semi-habituated elephants are attracted to orange halves and if so, how long to they take to inspect/consume all food items.

	Row 1	Row 2	Row 3
Cob number	1	6	11
Treatment	Untreated	Untreated	Untreated
Consumed			
Handled			
Inspected			
Video:			
Cob number	2	7	12
Treatment	Untreated	Untreated	Untreated.
Consumed			
Handled			
Inspected			
Video:			
Cob number	3	8	13
Treatment	Untreated	Untreated	Untreated
Consumed			
Handled			
Inspected			
Video:			
Cob number	4	9	14
Treatment	Untreated	Untreated	Untreated
Consumed			
Handled			
Inspected			
Video:			
Cob number	5	10	15
Treatment	Untreated	Untreated	Untreated
Consumed			
Handled			
Inspected			
Video:			

Appendix 2 (Trial 2)

Experimental design to determine whether semi-habituated elephants avoid treated orange halves in the presence of untreated orange halves.

	Row 1	Row 2	Row 3
Cob number	1	6	11
Treatment	Untreated	5% water miscible ChileGuard	5% oil soluble ChileGuard
Consumed			
Handled			
Inspected			
Video:			
Cob number	2	7	12
Treatment	5% water miscible ChileGuard	Untreated	5% water soluble ChileGuard with sticker.
Consumed			
Handled			
Inspected			
Video:			
Cob number	3	8	13
Treatment	Untreated	5% oil soluble ChileGuard	5% water soluble ChileGuard with sticker.
Consumed			
Handled			
Inspected			
Video:			
Cob number	4	9	14
Treatment	Untreated	5% water soluble ChileGuard with sticker.	Untreated
Consumed			
Handled			
Inspected			
Video:			
Cob number	5	10	15
Treatment	5% oil soluble ChileGuard	5% water miscible ChileGuard	Untreated
Consumed			
Handled			
Inspected			
Video:			

Appendix 3 (Trial 3)

Experimental design to determine whether semi-habituated elephants avoid treated orange halves in the absence of untreated orange halves.

	Row 1	Row 2	Row 3
Cob number	1	6	11
Treatment	5% water soluble ChileGuard with sticker.	5% water miscible ChileGuard	5% oil soluble ChileGuard
Consumed			
Handled			
Inspected			
Video:			
Cob number	2	7	12
Treatment	5% water miscible ChileGuard	5% water soluble ChileGuard with sticker.	5% water soluble ChileGuard with sticker.
Consumed			
Handled			
Inspected			
Video:			
Cob number	3	8	13
Treatment	5% oil soluble ChileGuard	5% oil soluble ChileGuard	5% water soluble ChileGuard with sticker.
Consumed			
Handled			
Inspected			
Video:			
Cob number	4	9	14
Treatment	5% water miscible ChileGuard	5% water soluble ChileGuard with sticker.	5% water miscible ChileGuard
Consumed			
Handled			
Inspected			
Video:			
Cob number	5	10	15
Treatment	5% oil soluble ChileGuard	5% water miscible ChileGuard	5% oil soluble ChileGuard
Consumed			
Handled			
Inspected			
Video:			

Appendix 4 (Trial 4)

Experimental design to determine the concentration at which semi-habituated elephants find treated orange halves repulsive.

	Row 1	Row 2	Row 3
Cob number	1	6	11
Treatment	Water only	1.5% water based ChileGuard with sticker	3% oil-based ChileGuard
Consumed			
Handled			
Inspected			
Video:			
Cob number	2	7	12
Treatment	1.5% water based ChileGuard	Sunflower oil only	3% water based ChileGuard with sticker
Consumed			
Handled			
Inspected			
Video:			
Cob number	3	8	13
Treatment	1.5% oil-based ChileGuard	5% water based ChileGuard with sticker	5% water based ChileGuard
Consumed			
Handled			
Inspected			
Video:			
Cob number	4	9	14
Treatment	5% oil-based ChileGuard	3% water based ChileGuard	Water and plant sticker only
Consumed			
Handled			
Inspected			
Video:			
Cob number	5	10	15
Treatment	4.5 % water based ChileGuard	4.5% water based ChileGuard with sticker	4.5 % oil-based ChileGuard
Consumed			
Handled			
Inspected			
Video:			

Appendix 5 (Trial 5)

Experimental design to determine how long after treatment do semi-habituated elephants find treated horse cubes repulsive.

	Row 1	Row 2	Row 3
Cob number	1	6	11
Treatment	2WEEKS: x% water based ChileGuard	2WEEKS: x% water with sticker ChileGuard	5WEEKS: x% water based ChileGuard
Consumed			
Handled			
Inspected			
Video:			
Cob number	2	7	12
Treatment	1WEEK: x% water based ChileGuard	3WEEKS: x% water with sticker ChileGuard	1WEEK: x% water with sticker ChileGuard
Consumed			
Handled			
Inspected			
Video:			
Cob number	3	8	13
Treatment	2WEEKS: x% oil based ChileGuard	1WEEK: x% oil based ChileGuard	4WEEKS: x% oil based ChileGuard
Consumed			
Handled			
Inspected			
Video:			
Cob number	4	9	14
Treatment	4WEEKS: x% water with sticker ChileGuard	4WEEKS: x% water based ChileGuard	5WEEKS: x% oil based ChileGuard
Consumed			
Handled			
Inspected			
Video:			
Cob number	5	10	15
Treatment	3WEEKS: x% water based ChileGuard	3WEEKS: x% oil based ChileGuard	5WEEKS: x% water with sticker ChileGuard
Consumed			
Handled			
Inspected			
Video:			

Appendix 6 (Trial 6)

Experimental design to determine at what spatial range do semi-habituated elephants find treated spatial barriers repulsive.

	Row 1	Row 2	Row 3
Cob number	1	6	11
Treatment	50cm: Rope 5% ChileGuard with x-type solvent	1m: Rope 5% ChileGuard with x-type solvent	3m: Rope 5% ChileGuard with x-type solvent
Consumed			
Handled			
Inspected			
Video:			
Cob number	2	7	12
Treatment	50cm: Rope 5% ChileGuard with x-type solvent	1m: Rope 5% ChileGuard with x-type solvent	3m: Rope 5% ChileGuard with x-type solvent
Consumed			
Handled			
Inspected			
Video:			
Cob number	3	8	13
Treatment	50cm: Rope 5% ChileGuard with x-type solvent	1m: Rope 5% ChileGuard with x-type solvent	3m: Rope 5% ChileGuard with x-type solvent
Consumed			
Handled			
Inspected			
Video:			
Cob number	4	9	14
Treatment	50cm: Rope 5% ChileGuard with x-type solvent	1m: Rope 5% ChileGuard with x-type solvent	3m: Rope 5% ChileGuard with x-type solvent
Consumed			
Handled			
Inspected			
Video:			
Cob number	5	10	15
Treatment	50cm: Rope 5% ChileGuard with x-type solvent	1m: Rope 5% ChileGuard with x-type solvent	3m: Rope 5% ChileGuard with x-type solvent
Consumed			
Handled			
Inspected			
Video:			