"Wolf depredation management: An investigation into the effectiveness of low-tech primary repellents causing stimuli disruption as potential methods of livestock protection from the Grey Wolf (*Canis lupus*)".

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Contents

Abstract

Introduction:

The issue of Human Wildlife conflicts 1
The effects of lethal control on Wolf populations ecological repercussions 2
Predation upon Livestock 3
Non lethal control 3
Factors affecting research 5

Aims and Objectives: 6

Methodology: 7

Results and Analysis: 10
Individual repellents and group responses 10
Collective responses towards all repellents 18
Fearful behaviour 20

Discussion: 23
Outcomes of the experiment and their implications 23
Application in the field 28
Relevance for carnivore reintroduction programmes 35
Evaluation and conclusions 35

References cited: 38

Appendices:

Appendix A: Raw Data
Appendix B: Experimental notes
Appendix C: Full ANOVA tables and omitted data
Appendix D: Plates (Test subjects and Test sites)

Tables

Table 1. Ethogram record table 8
Table 2.1. ANOVA results: Group 1: Individual repellents 10
Table 2.2. ANOVA results: Group 2: Individual repellents 12
Table 2.3. ANOVA results: Group 3: Individual repellents 13
Table 3.1. ANOVA results. All Repellents collective responses 18
Table 3.2. Multiple factor ANOVA: Interactions between factors that may have affected behaviour (all groups and all repellents) 19
Table 4: Multiple factorial Univariate ANOVA, effects upon proportions of fearful behaviour 21
Table 5: Factors affecting Fearful behaviour towards Cd's and Silent Roar 21

Figures

Figure 1: Behaviours expressed by each group across weeks for each repellent 15
Figure 2: Behaviour of groups towards repellents (All weeks) 17
Figure 3. Average response to repellents (all groups, all weeks) 18
Figure 4: Fearful behaviour across weeks (all groups) 22

Plates

Plates can all be found in Appendix D

Plate 1: Mai and Me. Showing the level of familiarity with the test subjects
Plate 2: Mosi
Plate 3: Duma and Dakota
Plate 4: Torak and Me. Showing familiarity with test subjects.
Plate 5: The UK Wolf Conservation trust (test site)

Abstract

Recent studies have shown Wolves to be a valuable keystone predator providing many irreplaceable ecosystem services. Human wildlife conflicts have been a major cause of extirpation and decline in Wolf populations from many parts of the world. Depredation upon livestock and over-zealous human retaliation are a major problem in the conservation of large carnivores. Low-tech, inexpensive, non-lethal depredation controls would be a valuable conservation tool in parts of the world such as eastern Europe where Carnivores are persecuted because of livestock losses. Low-tech stimuli disrupting repellents could offer a solution and alternative to lethal control and easily be incorporated into traditional husbandry and management schemes.

The experiment tested the effects of five potential repellents upon the behaviour of three test groups of captive Wolves. Proportions of Inquisitive, Fearful and Oblivious behaviour exhibited towards repellents were collated and analysed. Flagging and Wind Chimes were found to have significant effects upon the behaviour of groups two and three, eliciting high levels of fear which did not succumb to habituation over the thirty five day test period. Silent Roar (Lion scented faecal pellets in string bags) significantly impacted the behaviour of a lone male Wolf (group three). Fearful behaviour towards Cd's and Silent roar showed significant signs of habituation over the test period.

Some repellents tested showed promise as Wolf deterrents, and could possible be used as part of an integrated adaptive depredation management programme. Only once human, environmental, carnivore and site specific factors are taken into account can an adaptable management plan be implemented and conservation of large carnivores achieve success. It is of utmost importance to keep striving to discover and test the effectiveness and field application of non-lethal depredation controls if large carnivores and humans are to co-exist peacefully.

Introduction

The issue of Human-Predator conflicts:

Human Wildlife conflicts arise when wildlife activities coincide with mans and reach a level deemed unacceptable [3, 11]. Conflicts often result in disproportionate deaths of animals deemed responsible [6] and are becoming increasingly significant as human populations increasingly encroach upon remaining habitats [16]. Lethal methods are often seen as a final solution and have been used historically [3, 13]. Only in recent times has western man begun to alter attitudes towards eradicating problem animals [17].

Large predators are controversial. Different groups and cultures view them as desirable or undesirable [1]. Predators in general have been viewed negatively due to effects upon agriculture involving livestock predation and economic cost [1, 8, 17]. Wolf damages are often perceived as higher than real damages [25]. On the world scale predation upon livestock is economically insignificant. The U.S livestock industry accounts for less than one percent of gross economy. Of this three percent of sales (1999) were lost due to predation. Therefore only 0.0003 percent of U.S economy was lost due to predation [12]. However two percent of gross sales are spent upon predation prevention, so the sheep industry loses five percent of its gross sales to predation [12]. This may seem small but impacts on local scales for farmers whom this income is their livelihood. In many cases a few producers or hot spots absorb the majority of losses and suffer increased costs and reduced animal performance [10, 11]. In these areas “the wolf is still seen as a nuisance”, “predation upon livestock is the crucial factor in wolf persecution” [8]. Therefore, “protecting livestock reduces the necessity for killing wolves” [7].

Vertebrate predators, large size, mobility and extensive home range ensure that they figure prominently in the public eye [1]. “The overall impact of wolves upon the livestock industry was small, relative to other factors such as disease, birthing problems, weather and accidents” [10]. As with other problem animals like elephants, severe localised damage may occur [16]. Even though these animals are not the most damaging pest, their size and danger or perceived risk to people results in higher profiles and generally less tolerance [16].

The effects of lethal control on Wolf populations and its ecological repercussions

"Lethal control has had devastating impacts on some predator populations" [13]. In areas such as the UK many large carnivores including wolves are now extinct. Most large mammalian predators have been lost from 95-99 percent of the contiguous US and Mexico [20]. "Populations of wolves have been so decimated in the forty eight conterminous United States that they are now protected under U.S endangered species act" [17]. Many forces that caused carnivore decline are still operating, and if continued at current levels large carnivores may cease to exist except in a few wild areas and zoo's [17]. It is of great importance to avoid excessive lethal control and develop non-lethal methods to deal with conflicts and aid carnivore conservation [2], but not just for moral reasons.

Many ecological communities are either missing dominant selective forces or are dependent upon humans [20].Grey wolves are a top trophic level keystone predator, regulating Elk, Moose and Coyote populations, with some effect upon Bison [9]. In the southern greater Yellowstone ecosystem a "cascade of ecological events were triggered by the local extinction of Grizzly bears (*Ursus arctos*) and Wolves (*Canis lupus*)" [20]. Without top down control riparian dependent moose (*Alces alces*) populations erupted resulting in alteration of riparian vegetation structure and density which had a coincident reduction of avian Neotropical migrants in impacted willow, cottonwood and alder. Avian species richness and nesting density varied inversely with moose density [20]. Wolf reintroduction caused an indirect increase in lower flood plain riparian vegetation and consequently river bank stability [9]. Returning bank side vegetation such as Willow and Aspen was of importance to moose, birds, pollinators and small mammal populations such as beaver [9]. Increased leaf litter accumulation for decomposition is expected to positively affect nutrient cycling and its dependent organisms [9]. Wolves provide valuable ecosystem services that benefit humans in terms of river maintenance, control of grazers and indirectly promoting pollinators and plant growth which are essential for human existence along with likely many unknown benefits. Wolves provide a scavengeable food source for Ravens, Shrews, Foxes and Coyotes which has positive implications for farming [9]. It is not only moral to seek non-lethal solutions to conflicts but has direct benefits for man as well as nature.

Livestock Predation

Studies in Southern Europe showed that ungulates have been the wolfs' main dietary component [8]. In North America, North and Eastern Europe wolves feed mainly on wild herbivores, in Southern Europe wolves have apparently adapted to feeding upon fruit, rubbish, livestock and small-medium sized mammals [8]. "Little is known regarding patterns and processes of wolves preying upon livestock and effective ways to mitigate this conflict" [10], however it is thought that selection of wild or domestic ungulate prey is greatly influenced by local abundance but also by accessibility due to husbandry techniques [8, 10]. "The wolf diet in Iberia is based almost exclusively on domestic animals, due to the low number of natural prey" [18], whereas in viable ecosystems such as Yellowstone wolves killed less than 0.01 percent of total livestock [9]. Husbandry techniques play a vital role in levels of livestock predation. Livestock losses appear lower in parts of Europe where wolves were never extirpated, these livestock producers never lost the know how to protect their herds nor developed attitudes that governments should assist in dealing with wolves [4]. Wolves gaining sustenance from agricultural activities similarly to crop raiding elephants will likely return to areas where previous success occurred [16].

Non lethal control

Non-lethal methods apart from solving conflicts in a conservational way also manage predation allowing continuance of territorial defence and may have longer term effects preventing other predators from intruding into livestock areas [2]. Clever application of biological theory along with innovative inexpensive technologies could go a long way toward promoting co-existence [6]. Some methods of livestock protection mainly high-tech ones such as Radio Activated Guards or electric fences are simply just too expensive for most except affluent stakeholders [6, 11, 18].

Co-existence of predators and livestock is a luxury that may at present be unaffordable in some countries [6]. Providing small-scale inexpensive solutions to conflicts is important [2]. Most likely successful non-lethal interventions will be varied and flexible, using several different deterrents in combination or serially to avoid habituation by wildlife [3]. There has been some research into the effectiveness of deterrents and primary stimuli disruptors such as fladry, strobe and acoustic devices, however further research is needed to determine whether other objects are capable of effects similar to fladry and other successful disruptors [2, 7]. Barrier fences with stimuli disruptors could play an important role among the limited set of preventive measures available offering cost-effective mitigation to livestock depredation on local scales [7]. It's important to research not only success of potential stimuli disruptors but to use data upon wolf behaviour patterns to devise appropriate methods of application.

Primary repellents immediately disrupt a predator's action through a number of mechanisms such as neophobia, irritation or pain. Stimuli are visual, chemical or auditory [2, 5]. Wild animals especially wolves appear to be inherently wary of new stimuli (neophobic) [2, 3, 6]. Disruptive stimulus approaches show potential due to their low cost and simplicity however predators rarely form a conditioned response and will eventually habituate [6] and lose responsiveness and fear due to lack of consequences after exposure [14]. It would be useful to discover more disruptors which could possibly be used in a rotational system or that could show effectiveness in the many diverse situations in which predation on livestock occurs [19]. Habituation to disruptors/ repellents could be prolonged through alternation of stimuli, location and presentation, ideally focusing on the most susceptible livestock [2, 6, 16, 19].

Fladry is an ancient Eastern European technique which involves hanging flags (red and grey seem to work best [18]) on low held rope, traditionally used to shepherd wolves during hunting [2, 4, 6, 7, 10, 18]. Previous experiments with fladry and other repellents such as flashing lights or noise makers have showed some signs of success but usually only for short periods or small areas [2, 4, 5, 7, 10, 11, 13, 16, 18, 19] with fladry being the most successful lasting for up to sixty days with wild wolves [6, 7, 21]. Further success could occur with electrified fladry [5]. Disruptors work by decreasing patch profitability in terms of time and energy and wolves ideally should leave to seek alternative prey [7].

Captive born Tamarins and other herbivores have shown aversion and avoidance of predator scents and even without prior exposure distinguish between non-predatory and predatory faecal scents. It is possible that wolves could show similar aversion to big predator scents.

Factor affecting research

Field studies are notoriously hard to plan and coordinate in order to test non lethal protection in a controlled situation [22, 23]. One livestock casualty is often met with abandonment of test protocol and true effects will not be known, often non-lethal techniques will lower but not completely stop livestock predation [22]. Due to these factors and the difficulty of attaining responses in the field this experiment was carried pout with captive wolves. The Wolves used were of differing sub species with most test subjects being of North American subspecies and only one wolf being of half Eurasian subspecies for which these low tech disruptors are intended. "While there is much variation and some sub-specific distinction within extant populations of the Grey Wolf; there is considerable affinity between populations of Wolves in N. America and Eurasia" [4]. North American and Eurasian subspecies of wolves both share recent common ancestry, and are descended from *Canis mosbachensis* [4].

Wolves are known to occupy territories between 5.5 and 433.5 kilometres squared and roam as far as 100,000 kilometres squared [4]. It is therefore unpredictable how often wolves would come across repellents and habituate in the wild. Due to this, testing was set at random periods between calendar weeks. Familiarity with the wolves was ensured to rule out potential wariness caused by humans as seen in previous experiments [7].

Aims:

- To establish the effectiveness of different low-tech primary repellents.

There were no direct hypotheses for this investigation because one repellent was not being tested against another. Multiple repellents were tested in the hope of finding one which had some level of success. However it was anticipated that signs of habituation towards the repellents would occur as exposure increased, and thus it was expected that proportions of wary behaviour would decrease whilst inquisitive and oblivious behaviour increase.

Objectives (In chronological order):

- Observe and collect quantitative data on the responsive behaviour of grey wolves to a range of potential primary repellents placed along a rope fence.
- A combination of the best repellents were ideally intended to be tested together, however time and staffing constraints did not permit this.
- Collect data over a period to see if and during what time-frame habituation occurs.
- Suggest which primary repellents, if any, could be used to assist in prevention of livestock predation by grey wolves.
- Suggest appropriate rotational methods of primary repellent application (if needed).
- Suggest further experiments that could be carried out in order to build upon the knowledge base regarding repellents in order to help better their application.
- Explore factors, which may have affected Wolf responses to repellents.

Methodologies:

Testing sessions were undertaken at The UK wolf Conservation Trust, Butlers Farm, Beenham, Reading, Berkshire, RG7 5NT. (An image of the site can be seen in Appendix D).

The groups of Wolves tested (Appendix D) were of the following sub-species

- 1. North American Mackenzie River valley (*Canis lupus occidentalis*) 2x female (maturing 2yrs old) Mai and Mosi.
- 2. North American (*Canis lupus*) 2x female (adults) Duma and Dakota.
- 3. 1x male half Eurasian half North American (maturing aged 2 yrs) Torak.

The testing occurred during August and September 2008 with tests occurring once a week for a total of six test sessions. The wolves required handlers for safety and to meet the requirements of the Wolf Trust. Groups were tested in a random order each test session, mainly determined by the Wolves' willingness to come and be placed on a chain. Wolves were walked up to the fencing by handlers and encouraged away after five minutes and kept aside whilst repellents were changed, until each repellent had been presented.

Each individual repellent test was a five minute continuous observational ethogram (Table 1) observing the wolves' behaviour towards the repellent. Repellents were presented in a random order. Due to behavioural characteristics/ personalities and the advice of handlers at the wolf sanctuary, the females were tested in their pack pairs and the male singularly. Group interactions may affect behaviour; however wolves are generally pack animals in the wild so responses were expected to be comparable. Interactions with two required handlers and myself could not be helped, handlers were informed not to restrict movement (using a chain) unless necessary to prevent harm. Upon advice from the trust observations occurred at close range. It was discovered in a dummy run that my standing at a distance was a distraction. Due to familiarity with the wolves, myself and handlers were of little distraction. During ethograms the number of times wolves portrayed inquisitive, fearful or oblivious behaviour towards the particular repellent was recorded, when involving a repellent that created sound or movement it was noted if behaviour occurred after noise or movement occurred. Oblivious behaviour was recorded whether near or away from repellents. Whether the wolf passed through fencing was also recorded. The behaviours were identified by descriptions below devised from Mech and Boitani (2003). Observations of general behaviour were also noted such as attempts to grab or sniffing at the repellent, as well as weather conditions and other factors which may have influenced behaviour.

1. Inquisitive: The tail will be held in a normal position, down but not flat against the behind, it may have a slight s-shape to it showing uncertainty. The wolf will observe the object and may approach the repellent, smell, taste and even touch or move it. Ears will be upright, pert and attentative.
2. Fearful or wary: The wolf will be skittish, with tail low and straight maybe even between the legs. Ears will likely be aimed backwards, maybe flattened to the head. The mouth will be closed. The head will be lowered with the neck extended.
3. Oblivious: The wolf will not pay attention to the fencing. Body posture will be normal, tail down but not flat against the body, head and ears upright.

Table 1. Ethogram record table

Behaviour type	Inquisitive	Fearful or wary	Oblivious
Times occurred			

Did the wolf pass through the fence, if so how many times? _ _ _ _

With time and permission permitting further testing would have ideally been carried out with the repellents blocking food. Repellents were attached at intervals approximately 25-50cm apart depending on the size of the repellent as per the recommendations of Musiani and Visalberghi 2001 [21] to a two tiered plastic wire fence of one metre in height with repellents hanging between 50 and 80cm from the ground depending on their length. Wolves could not gain entry through a wooden fence easily and such a fence would be permanent in real life situations potentially restricting movements of other wildlife [24], it would also be expensive in terms of materials and labour.

Safety procedures of The UK Wolf Conservation Trust (UKWCT) and those incurred by the risk assessment were adhered to. Repellents tested are the first five equipment items.

Equipment list:

- Flagging made of canvas-like material, mainly red with some white (Approximately 50x75cm).
- Cd's with reflective and coloured surfaces.
- Bells (Small Approximately 2cm diameter) attached to fencing by green string.
- Wind chimes (metal and string).
- Lion scent (Silent roar) in the form of sterilized faecal pellets placed in netted drawstring bags for the wolves' safety (to prevent consumption). However adding a visual component whilst allowing scent to permeate.

- Metal steaks to be placed in the ground for fencing.
- Plastic washing line wire
- Metal chains for walking the wolves and safety from escape.
- Trained wolf handlers.
- Ethogram sheets.
- Hammer and other tools for erecting fencing.
- First Aid kit
- Walking boots weather appropriate and waterproof clothing.

Results

Full raw data can be seen in Appendix A. Notes taken during test sessions can be seen in Appendix B. Full ANOVA tables can be found in Appendix C.

2 way ANOVA tests: Individual repellents. Did arcsine proportions of behaviour change over weeks? Was behaviour towards the repellents non-random?

Standard 95% confidence levels are assumed for significance, I.E <0.05

Table 2.1. ANOVA results: Group 1: Individual repellents

Repellent	**Week**	**Behaviour**
Bell	0.710	0.136
Flagging	0.999	0.273
Wind Chimes	0.994	0.074
Cd's	0.991	0.436
Silent roar	0.999	0.174

It can be seen from table 2.1 that week or exposure had no significant effect upon the proportions of behaviour exhibited. Behaviour exhibited was random; repellents had no significant effect upon the proportions of fearful, inquisitive and oblivious behaviours exhibited.

Observations of reactions to repellents:

Bell

The Wolves were unfearful when exposed to the bells, making contact with the repellents and even making attempts to walk through fencing. Bells were abandoned due to time constraints, as they showed little effect.

Flagging

The Wolves skirted round the flagging, occasionally whimpered and got spooked after movements. Hostility cut-off signals in the form of licking lips through closed mouths were exhibited, showing signs of fear towards the flags. These effects were seen throughout the testing period, although less attention appeared to be shown in latter weeks, however flags were still avoided. Interestingly the Alpha female Mai did not approach or investigate fencing, only the lower ranking Mosi made any contact or approached the flagging; however she was still generally wary.

Wind Chimes

Initially the wolves were wary of chimes and spooked after sounds. Interest in the chimes appeared to decline over time even when sounds were made. The alpha, Mai remained wary. Both wolves got distracted sometimes catching mice in the field.

Cd's

Wolves were slightly wary at first, however this behaviour subsided to inquisitiveness or paying little attention. On a particularly sunny day (week 5) Mosi the lower ranking female was even playful and continually grabbed at the Cd's showing very little fear. Mai was wary at times but still approached the fence on occasion.

Silent roar

Wolves showed wariness but also inquisitively smelled the air throughout the test period. Mosi was very interested in the fencing and made attempts to grab it throughout culminating in her breaking the fence in the final test. Mai the alpha was more wary and as with most repellents stayed at a distance.

Table 2.2. ANOVA results: Group 2: Individual repellents

Repellent	**Week**	**Behaviour**
Bell	0.977	0.914
Flagging	0.995	0.026
Wind Chimes	0.992	0.024
Cd's	1.000	0.404
Silent roar	0.992	0.226

Table 2.2 clearly shows that exposure or time had no significant effect upon proportions of behaviour exhibited. Behaviour was significantly non-random for flagging and wind chimes. Flagging and Wind chime repellents had a significant effect upon how the Wolves behaved. The other repellents did not significantly impact the Wolves behaviour.

Observations

Bell

wolves were mildly wary at first but showed little fear in general, occasionally trying to grab the fencing.

Flagging

Duma the Alpha Wolf was constantly wary, and didn't approach the flagging, constantly staying at a distance. Dakota was extremely timid at first but became more inquisitive over time, making contact with the fence and was very intent on grabbing the flags in the final test session.

Wind Chimes

Both Wolves were fearful of the chimes, especially after noises were created. Dakota the lower ranking female made attempts to grab the chimes however was still generally set back by the sounds of the chimes.

Cd's

Little interest was paid to the Cd's initially. Duma generally avoided them and Dakota sporadically attempted to grab the fencing but was generally oblivious.

Silent roar

Wolves were somewhat intrigued sniffing the air often. Duma was more wary whilst Dakota the lower ranking female far was less timid and inspected the fence throughout the test period eventually tearing the fence apart in order to taste the pellets

Table 2.3. ANOVA results: Group 3: Individual repellents

Repellent	**Week**	**Behaviour**
Bell	0.954	0.358
Flagging	1.000	0.009
Wind Chimes	0.997	0.014
Cd's	1.000	0.120
Silent roar	0.994	0.045

Table 2.3 shows no significant change in the proportions of behaviour exhibited as Wolves were increasingly exposed to repellents. Torak's behaviour was significantly affected by flagging, Wind chimes and Silent roar. The proportions of behaviour he exhibited were different, non-random and specific re-actions to the repellents. The other repellents showed no effects.

Observations

Bell

Generally showed no signs of interest towards the bells, mainly oblivious.

Flagging

Torak had a very strong aversion to flagging and was fearful consistently over the entire test period, generally avoiding the flags, making little eye contact and even hiding behind myself and other handlers. Constantly wary with ears back and tail tucked Torak was very anxious, although began to show slightly increased interest approaching the fence more closely towards the later weeks however still timidly.

Wind Chimes

Torak was initially fearful of the chimes, making little eye contact and skirting round the fencing, often jumpily when the chimes made sounds. Torak became bolder as exposure increased but was still generally far more wary than the other groups

Cd's

Torak generally skirted around the fencing and was wary to start with but appeared to become more oblivious towards the Cd's over time; however he rarely approached the fence throughout the test period.

Silent roar

Torak was generally wary throughout, low eye contact and fearful body postures were exhibited. Torak did sniff the air assumably taking in the scent from the pellet bags. Cut-off signals (licking the lips through an otherwise closed mouth) were observed presumably aimed towards the fencing in order to discontinue negative actions.

Figure 1: Behaviours expressed by each group across weeks for each repellent.

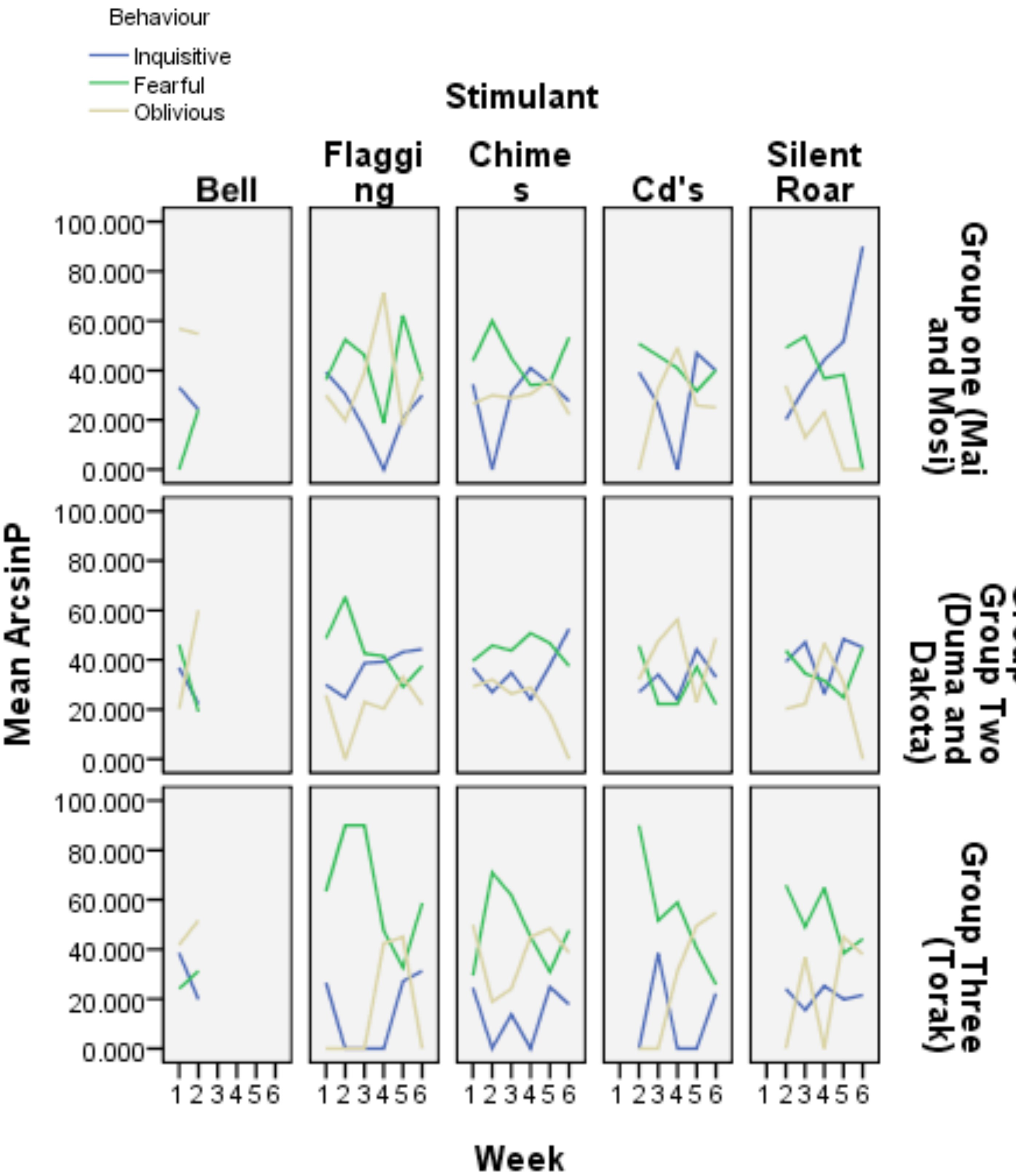

Figure 1 shows how arcsine proportions of behaviours exhibited changed over weeks. These effects can be seen for all repellents and for each group. Firstly of particular note in concordance with ANOVA results are the behaviours of group three towards flagging, wind chimes and silent roar, which all clearly show high levels of fearful behaviour throughout the test period. Inquisitive behaviour is low throughout, with fluctuating levels of oblivious behaviour. It is important to note that levels of fear are higher in group three than the other groups. It can be seen that group two shows high levels of fear for flagging and wind chimes with low levels of oblivious behaviour and medial rates of inquisitiveness. This coincides with statistical evidence although the levels of behaviour are not as extremely separated as group three. Other repellents do not show significantly strong relationships between behaviour proportions across weeks or behaviour types exhibited, in terms of statistical analysis. However, looking at the graphs for behaviour in group one; fear and obliviousness to silent roar appear to give way to inquisitive behaviour as exposure increased, possibly suggesting signs of habituation. Similarly to groups two and three, although not statistically significant and fluctuating across weeks, fear appears to be exhibited more than other behaviours for flagging and wind chimes. It can be seen that fearful behaviour was low for bells in all groups, which is why they were chosen to be abandoned. There are clear separations in behaviour in group three with fear seeming to dominate for most repellents but to varying degrees. Group two’s behaviours was generally more tightly packed showing almost equal amounts of each behaviour except in the case of flagging and wind chimes. Group ones behaviour however, was much more erratic and has high fluctuations between weeks; it is possible that the young age of these wolves might be a driving force behind more varied actions.

Figure 2: Behaviour of groups towards repellents (All weeks)

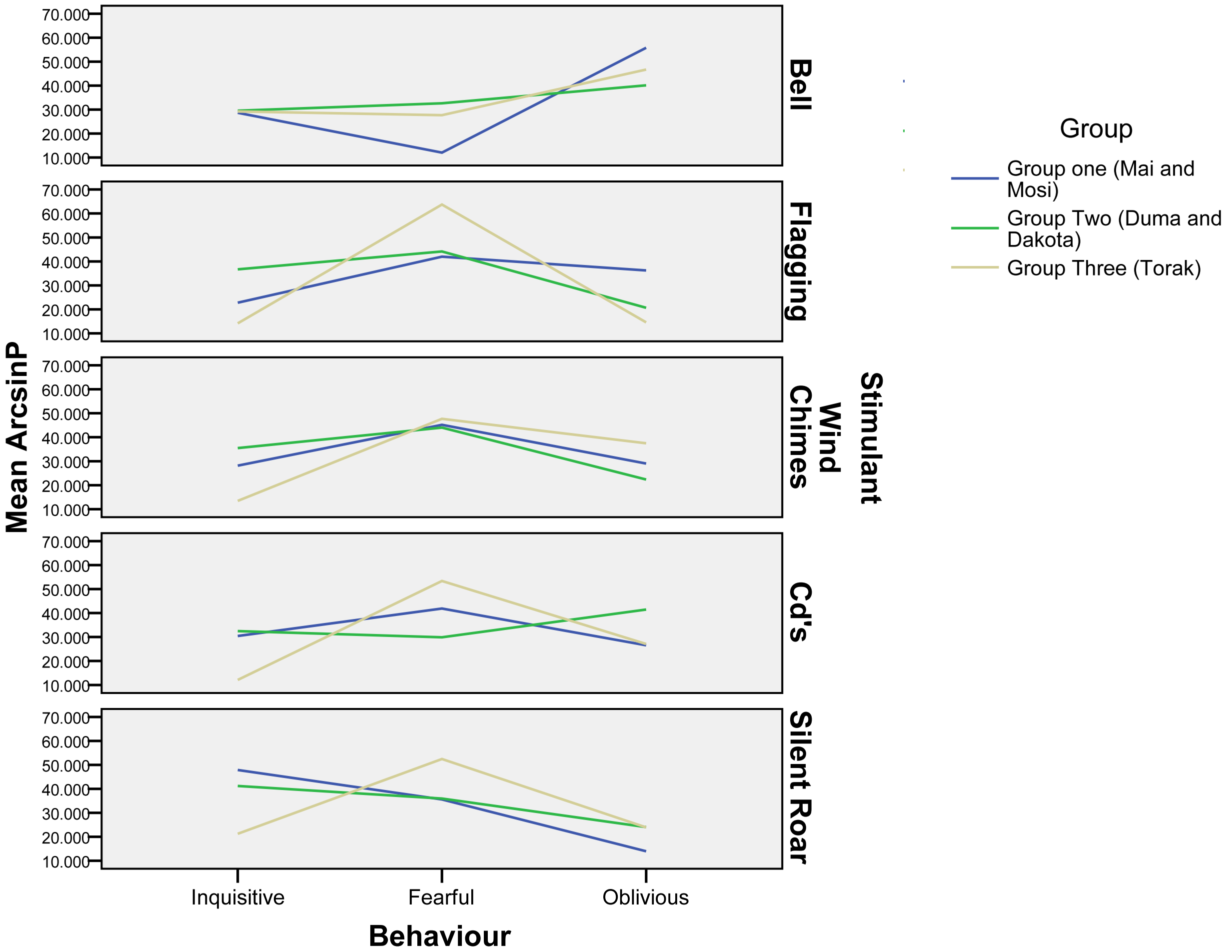

Figure 2 shows average behavioural responses of the test groups to repellents. All groups showed high levels of oblivious behaviour towards bells. All groups had a peak in fearful behaviour towards flagging and wind chimes; there was an extremely marked peak in fearful behaviour of group three towards flagging. Group three had a peak in fear and a lull in inquisitive behaviour for all repellents except bells. Group three shows a marked peak in fearful behaviour towards silent roar; however groups one and two have peaks in inquisitive behaviour and lulls in oblivious behaviour suggesting that females are more interested and less fearful of lion scent and maybe the scent of other large predators. Cd's were responded to in almost even (random) behavioural proportions amongst groups one and two.

2 way ANOVA results. In general (all repellents) did arcsine proportions of behaviour change over weeks? Was behaviour non-random?

Table 3.1. ANOVA results. All Repellents collective responses

Group	**Week**	**Behaviour**
1	1.000	0.164
2	0.997	0.013
3	0.996	<0.001

Table 3.1 shows no significant effects of exposure upon the proportions of behaviour exhibited for all repellents collectively. However, behaviour exhibited by groups two and three was not random, I.E. repellents and fencing in general had effect upon the way the Wolves acted. There was no significance for group one.

Figure 3. Average response to repellents (all groups, all weeks)

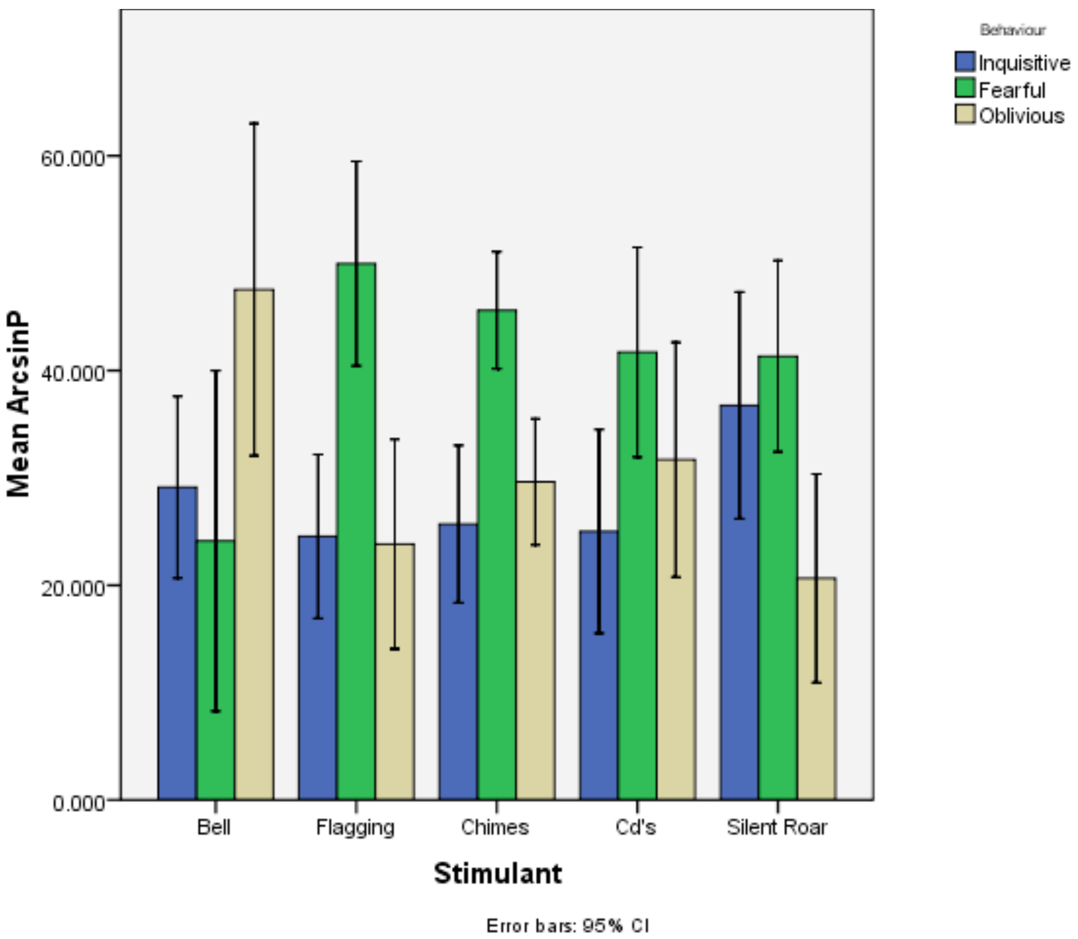

Figure 3 shows the average behavioural responses of all the Wolves from all test sessions towards each repellent. It is clear that fearful behaviour is very low for Bells, with oblivious behaviour being high, these were the least effective. Looking at the graph and other evidence it becomes possible to design a hierarchy of effectiveness.

1. Flagging
2. Chimes
3. Silent roar
4. Cd's
5. Bells

It is clear that Flagging was the most effective repellent, eliciting the most fear, with comparably lower amount of oblivious and inquisitive behaviour (Fig.2. Fig.3. Table 2.2 and Table 2.3). Wind Chimes had similar effects. Silent roar generating a high level of fearful behaviour, showed statistically significant effects in group three, yet inquisitive behaviour was also high. This would not be good for protecting livestock if Wolves were interested in the fence which is supposed to protect them, but did give low levels of oblivious behaviour. Cd's although not statistically showing evidence of influence upon behaviour, did generate a high level fearful response, however oblivious behaviour was quite high also.

Table 3.2. Multiple factor ANOVA: Interactions between factors that may have affected behaviour (all groups and all repellents)

Factor(s)	Significance
Behaviour	0.27
Group	0.32
Week	0.999
Behaviour*Group	0.005
Behaviour*Week	0.038
Group*Week	1.000
Behaviour*Group*Week	0.102

Table 3.2 shows the effects of various factors and multiple factor interactions upon proportions of behaviour exhibited by all groups for all repellents. It can be seen that behaviour was significantly non-random; behaviours exhibited were directly affected by repellents. Group had significant effects upon proportions of behaviour exhibited, it can be inferred that different groups responded in significantly different ways towards the repellents. Proportions of behaviour were not significantly affected by exposure (week). As could be expected due to their individual significances, the combined effects of behavioural actions and group resulted in significant effects upon proportions of behaviour exhibited. Behaviour amongst the different groups was non-random, I.E. Groups responded to the repellents in different ways with differing proportions of behaviours. Surprisingly, although exposure showed no significant effects upon individual repellents and groups; exposures (week) combined effects with behavioural actions had a significant effect upon proportions of behaviour exhibited. It could be inferred that behavioural responses changed across weeks. No other interactions between factors showed significance.

Fearful behaviour:

Fear is the behaviour that a successful repellent will ideally elicit. It is important to investigate if different repellents induce different levels of fear and how fear towards repellents changes over weeks, I.E. do wolves habituate and become less fearful after increased exposure to repellents. It is also imperative to investigate other factors that may affect levels of fear.

Table 4: Multiple factorial Univariate ANOVA, effects upon proportions of fearful behaviour

Factor(s)	Significance
Group	0.029
Stimulant	0.001
Week	0.055
Group*Stimulant	0.456
Group*Week	0.251
Stimulant*Week	0.716

Table four shows significant effects upon fearful behaviour by group and stimulant. I.E. different stimulants gave different levels of fearful response, and each group reacted to repellents with differing levels of fear (fig. 3). The differences in group responses are also apparent (fig. 2.) There were no significant interactions between factors. Week did not show significant effects upon proportions of behaviour. However it is worth highlighting week as it was close to being significant. It is possible that the relatively consistent fear towards Flagging and Wind chimes overshadowed the significant changes across weeks that are apparent in Cd's and Silent roar (fig. 4.) and affected the significance score.

Table 5: Factors affecting Fearful behaviour towards Cd's and Silent Roar

Factor	Significance
Group	0.030
Week	<0.001
Group*Week	0.148

Table five shows that group and week significantly effected proportions of behaviour for Cd's and Silent roar. The Wolves show signs of habituation to these two repellents in terms of fear shown, with fear decreasing as weeks went on (fig. 4). There is no significant interaction between group and week.

Figure 4: Fearful behaviour across weeks (all groups)

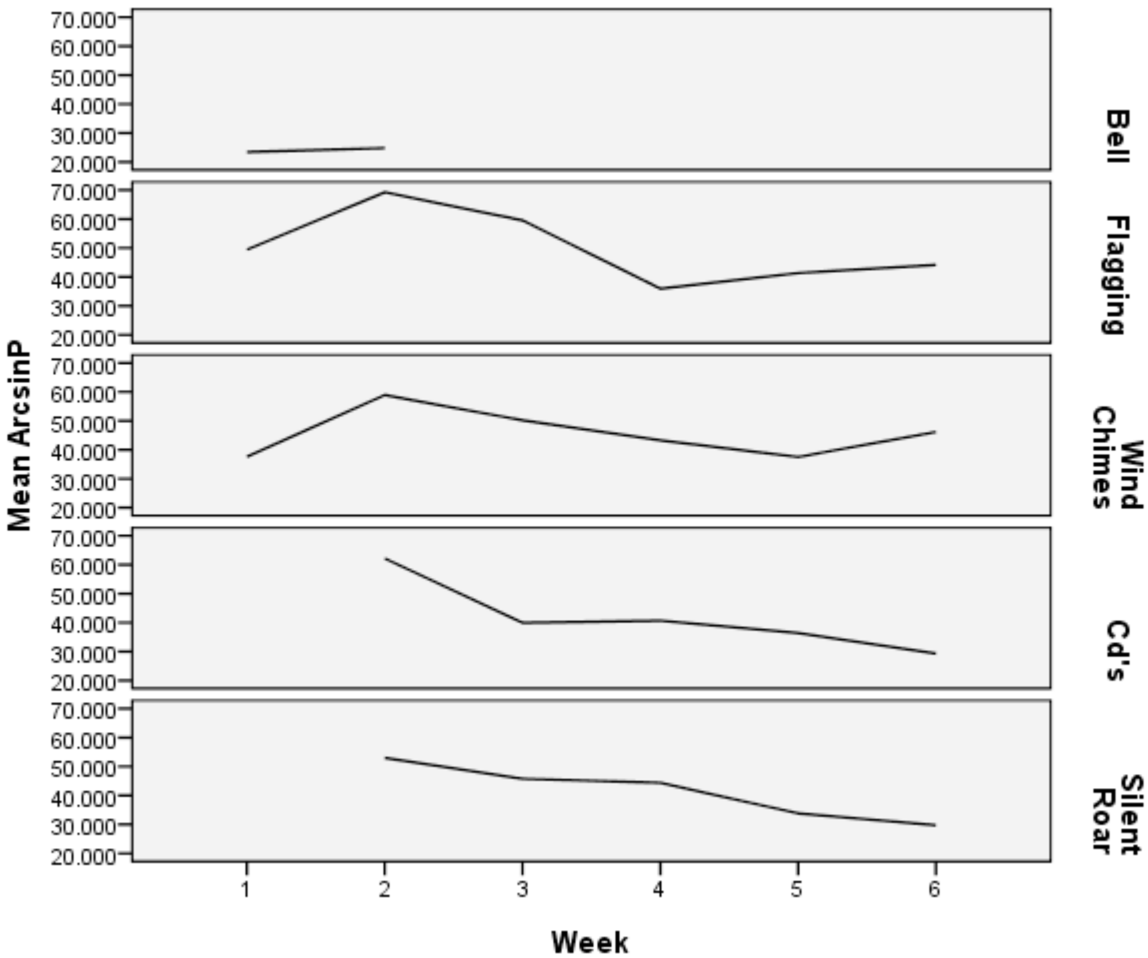

Figure 4 shows average levels of fearful behaviour displayed by all groups as exposure (week) increased. Fearful behaviour was constantly low for Bells. It can be seen that although fluctuating, levels of fear are extremely high for flagging and wind chimes; this behaviour is relatively constant across weeks although shows signs of gradual decline. Levels of fear towards Cd's and Silent roar show negative correlations. Both repellents show high initial levels of fear with a strong decline as exposure increases.

Additional data regarding the amount of contact wolves mad with repellents can be seen in Appendix C.

Discussion

Outcomes of the Experiment and their implications:

Group one showed no significant behavioural responses towards repellents; nevertheless group one as did groups two and three, yielded other findings regarding pack behaviour and individual differences in response. Groups two and three show statistically significant behavioural responses towards some of the disruptive stimuli tested, giving further evidence of the usefulness of non-lethal repellents. Fearful behaviour was found to be significantly dependent upon the repellent being tested, I.E the Wolves responded to the different repellents with variable levels of fear. Flagging, the most successful repellent showed strong statistical affects upon responsive behaviour exhibited by groups two and three (Tab 2.2. Tab 2.3.). High levels of fearful behaviour were maintained throughout the test period (Fig 1. Fig 2. Fig 3. Fig 4.). Interestingly, Wind chimes (which don't appear to have been tested before), showed almost as much success. Lion scented pellets in drawstring bags offering visual and olfactory stimuli (Silent roar) resulted in significantly non-random behaviour, eliciting fear in group three (Tab 2.3. Fig 1. Fig 2.) Groups One and Two were less fearful and more inquisitive (Fig 1. Fig 2.).

Bells were abandoned after two weeks due to an extreme lack of effectiveness and seemingly had no influence upon behaviour, eliciting very small amounts of fear. This may have been due to the small size of the bells (~2cm diameter) which did not generate a great deal of sound even when moved by the Wolves. The pitch of the bells was likely not aversive enough to cause fearful responses. Using larger bells spaced along an entire stretch of fencing may be costly, so inappropriate for non-affluent farmers, whom low-tech non-lethal repellents are aimed at. It could be that due to their lack of auditory shock bells need to be combined with visually disruptive stimuli in order to yield effect, but this is unlikely. Bells offer no real use in decreasing depredation and preventing Wolves accessing livestock; any effects will likely be very short lived.

Cd's showed more promise and yielded a reasonable amount of fearful response which appeared to decline due to exposure (Fig 1. Fig 2. Fig 3.). Statistically, Cd's did not have any affect upon behaviour and exposure did not have any significant effect upon proportions of behaviour exhibited. Group two seem to have a lot less fear towards cd's, this may be because they are older and have had more experience with reflective surfaces; it is often the case that experience plays a role in individual behaviour [26]. There appears to be fluctuation and alteration of behaviours exhibited by the Wolves in response to Cd's over time (Fig 1. Fig 2. Fig 3.). When looking at fearful responses only, it becomes clear and is statistically significant that Cd's initially generated higher levels of fear which deteriorated due to exposure (Tab 5. Fig 4). There appears to be very little if not no literature upon the effects of reflective surfaces on Canines. This is possibly because the visual system is harder to quantify than auditory or olfactory systems [4]. Cd's although showing some potential are unlikely to be productive in livestock protection and effects likely to be short lived and susceptible to habituation [27].

Fladry is a low-tech repellent which has been used for centuries in Eastern Europe to help channel Wolves during hunting, offering no physical barrier but a psychological one of wavy red flags which confuse and confound Wolves attempts to breach it [28, 29]. In recent years fladry has been adapted for use as an inexpensive tool in preventing livestock predation [30]. It has proved effective in many experiments involving both captive and wild Wolves and appears to deter Grey Wolves from entering fenced pastures [31]. It has been known to deter Wolves from their stereotypical movement patterns, even when placed in the way of food [27, 22]. Fladry was shown to have significant effects upon Wolf behaviour for two out of three test groups (Tab 2.2 and Tab 2.3); it elicited high levels of fear for all groups (Fig 2. Fig 3. Tab 4.).

Although its effectiveness in the wild is still not fully understood due to the range of environmental factors which may have effect; it has generally been found to be effective for sixty days [6, 7, 21], Gehring et al (2006) found Fladry offered farms at least 90 days protection from wolf attacks [32]. The testing period for this experiment lasted thirty five days, fearful behaviour towards flagging was high throughout (Fig 1. and Fig 4.) and increased exposure (number of test weeks) had no significant effect on behaviour towards flagging (Tab 2.1. Tab 2.2. Tab 2.3. Tab 4.). This gives further evidence to maintain Fladry's place in the quiver of conservational tools. However, as shown by the lesser response of group one and time frames involved in success, among other factors, there are concerns over its practical application [29].

Inquiries into traditional techniques in Central Portugal provided interesting findings on the use of different light mobile barriers; some similar to fladry used to protect sheep flocks kept in small enclosures (corrals) at night [25]. It is possible that there are many materials which could be used and alternated in concurrence with fladry. Wind chimes appear to operate in a similar way to fladry; although not as much of a visual presence chimes did startle the Wolves when creating sound and moving. Behaviour was generally quite fearful towards Chimes and elicited significant effects (Tab 2.2. Tab 2.3. and Tab 4.), which were maintained across the test period (Tab 4. and Fig 4.). Although statistically no habituation occurred during the test period (Tab 2.2. Tab 2.3. and Tab 4.), it was observed that Wolves seemed to become braver towards the later weeks, possibly indicating that habituation may have occurred over a longer testing period. Wind Chimes have shown potential as a tool in Non-lethal livestock protection and may prove to be useful as part of a rotational, multi-tool management system.

Interestingly sterilised Lion faecal pellets (Silent roar) had no significant effects on the behaviour of Groups one and Two (whom both had multiple members who were female), yet caused significant fear in group three (Lone Male) (Fig 2.1. Fig 2.2. Fig 2.3.). When looking at average response towards this repellent; similar to Cd's it appeared to show good potential, which was however short lived and fearful behaviour declined with increased exposure (Fig 4. Tab 5.). The sexual origin of the sterilised faecal pellets, whether from a male or female Lion source may have effect on behavioural responses. Silent roar appeared to cause fearful behaviour in the Male Wolf but inquisitive behaviour in the females. In an experiment by Epple et al (1995) Sex differences were found in responses of Mountain Beaver (*Aplodontia rufa)* to aversive Coyote (*Canis latrans)* urinary cues. Males appeared less sensitive than females [33]. It is possible that the same could be true for Wolves; depredation has been shown to vary with predator sex [34] so it is possible that sexes respond differently towards scent from other predators. Group three was however more fearful in general (Fig 1. Fig 2.).

The use of large predator scent has its place as a potential non-lethal management tool. Ideally scent from species that the wolf has evolved with and would conflict with in the wild, such as the brown bear (*Ursos arctos)* would have been used; however this scent was very hard to get hold of in the UK. The olfactory repellent β Chloro-acetyl chloride has been shown to be effective in preventing Coyotes accessing food sources, but is unfortunately a strong irritant to sheep so is impractical for use in close proximity [38]. Cinnamaldehyde showed promise, yet after testing 45 olfactory repellents Lehner, Krumm and Cringan (1976) found no chemical odour that consistently repelled Coyotes and dogs without adversely affecting sheep [38]. Further investigation into the effectiveness of natural enemy and other olfactory scents as deterrents is warranted.

Fear is important when investigating disruptive stimuli and if intense can disrupt behaviour or inhibit it totally [28, 37]. The repellents tested mainly act as psychological barriers [35, 36]. Fear and anxiety are defined as emotional states that cause perception of any factual danger (fear state) or possible danger that threatens the well-being of the individual [37]. An ideal repellent would create lasting phobia (fear is not extinguished but remains at high levels) [37] and disrupt predatory sequences idyllically leading to a retreat from livestock [28]. Situations that cause a feeling of insecurity and induce hormonal signs of stress include exposure to novelty [37]. To alleviate distress in aversive situations that are a threat to homeostasis, animals display an adaptive response to recent or anticipated danger which involves psycho-behavioural changes that nullify the effects of the trigger and neuro-endocrine adjustments necessary to maintain internal homeostasis [37].

Disruptive stimuli work on the basis of being novel and undesirable [28]. The behavioural response to aversive events vary greatly and the type and magnitude of neuro-endocrine arousal and behavioural expression are determined by; psychological factors (such as composition of stimulus), the amount of control that can be exerted upon challenging stimuli by the display of suitable behaviours and the physical properties of the triggering stimulus [37]. The more noxious the stimuli, the stronger the aversion [28].

The animal's ability to predict and control threatening events determines the neuro-endocrine patterns and intensity of emotions exhibited [37], predators may learn that random firing of repellents have nothing to do with there activity and over time may habituate and learn to cope with the repellent [24]. Low serotonin levels and active adrenal systems are associated with intimidated profiles, avoidance behaviours are more likely when adrenaline related circuits are active [26], these movements are part of an active strategy used to cope with fear [37]. Destruction and vocalization (which many of the wolves exhibited) are often used as an attempt to cope with fear [37]. Urination and defecation may be an intense reaction to a threatening stimulus [39]. Some of the wolves did urinate in the proximity of fencing, mainly during flagging tests, so it is possible that this was a further sign of fear towards the stimuli. As mentioned in the results Wolves made postural cut-off signals towards repellents, intended to cease negative actions, also intended to manage fear [39]. It is clear that fear towards aversive stimuli is a complex process and canines have many mechanisms for coping with stress and fear which makes habituation likely and the search to find long lasting repellents complex. Pairing stimuli with food (livestock), results in responses incompatible with fear; strengthening desensitization making habituation more likely [37].

The groups tested although displaying similar behaviour towards repellents to some extent, reacted in different ways (Fig 2). It was found that the group being tested had a significant effect upon the proportions of behaviour being exhibited and the level of fear shown towards repellents (Fig 4. Tab 3.2. Tab 4. and Tab 5.). Individual behaviour profiles; with variations in temperament in wolves have been found to be analogous to personality [26, 31]; individual wolves will respond to repellents in varying ways. Group three the lone male, in general showed higher levels of fear than the other groups. Torak is usually housed with group one and is the alpha male of the pack. Torak could have shown greater signs of stress due to what is known as separation anxiety, whereby stress is induced by his being separated from fellow pack members which is exacerbated by aversive stimuli [37]; possibly yielding higher levels of fear. Males also have less of a role in defence so this could explain Torak's lack of interaction with the repellents and high level of fear (Fig 1. Fig 2. and Appendix C, Omitted data)

The typical wolf pack is a family, with adult parents (Alpha's) guiding the activities of the group in a division of labour system [40]. Females predominate in defence [40], which may explain why groups One and Two were more actively involved with the fencing (Appendix C, Omitted contact data) showing less fearful behaviour. Interestingly it was observed in all groups with multiple pack members (1 and 2) that the Alpha female was more stand offish and acted far more like the lone Alpha male, and it was the lower ranking Wolf that inquired and was bold towards repellents, it may be that all alpha's interact and show more fear to aversive stimuli. Could it be that lower ranking wolves are deemed more dispensable, and through their experience as a lower pack member have personalities moulded to taking risks so alpha's do not have to [4, 40, 41]. Differences in individual behaviour and fear levels shown by pack members may have implications for the application of aversive non-lethal stimuli in wild situations. It is feasible that repellents could be relaxed or less effective repellents applied when stress and pack anxiety are already high during the breeding season [4, 41].

Application in the field

Non-lethal methods of depredation prevention have proved to possess some level of success [27], but before any repellents are applied in real-life situations, the human factors affecting wolf conservation need to be explored. Wolves have been historically persecuted due to predation upon livestock, and population decline has generally been attributable to human interference stemming from traditionally negative Judeo-Christian views [34, 42, 43, 44, 47]. Human intervention because of livestock depredation is still one of the major threats facing carnivore conservation worldwide [25, 34], in the last two centuries the Tasmanian Wolf and Falkland island Fox have gone extinct due to their role in livestock predation [34]. Human Wildlife conflicts occur when requirements overlap; demographic and social changes and mans increasing encroachment upon nature place more people in direct contact with wildlife, making conflicts more likely [29].

The public generally approves the use of non-lethal selective methods of depredation prevention, so long as they do not cause serious ecological damage [24]. Yet lethal control is still the main method of choice; and is likely to continue to be so unless long held traditionally negative attitudes towards Wolves change, and successful, affordable non-lethal methods are found; in order to achieve stakeholder participation [24, 30, 38, 45]. There appears to be common patterns for Canids, and Wolves in particular receive a disproportionate amount of attention in regards to their role in livestock loss in comparison to other factors such as weather and disease [34]. Wolf damages are often perceived as higher than real damages [31, 35, 45]. Collective damage of smaller species such as Jackals, Foxes, Coyotes, Mustelids and small Cats may be greater [31].

Public and stakeholder opposition can block translocations, re-introductions, conservation and the natural recovery of carnivores to former habitats [43]. Due primarily to predation on livestock some farmers and other interest groups oppose Wolf conservation [43]. There seems to be greater tolerance towards Wolf predation in parts of the world such as Eastern Europe and India where Wolves were never completely extirpated; with practices adjusted to their presence [48]. It is important to change public opinions and increase tolerance in areas with low acceptance towards Wolves [27, 31].

Value placed on wild animals depends heavily on species knowledge of local peoples; education is a major conservational tool in changing attitudes and promoting tolerance [31]. Targeting key groups (local populations and stakeholders) with education programmes, integrating human and ecological concerns greatly aid the promotion and implementation of non-lethal depredation control [29, 44]. Involving local communities and stakeholders in conservation processes, raising awareness of the essential role of wildlife in ecosystem functioning and the ethical, aesthetic, recreational and economic value of nature though the use of spokespeople within target groups is an invaluable conservational tool for the acceptance and operation of Non-lethal control [29, 44, 49]. Protecting local livelihoods, decreasing vulnerability and counteracting losses with benefits all help foster community based conservation [29]. Conservational explanations are sometimes accepted by communities, gaining their involvement in conservation schemes [45]. Long term studies of radio collared carnivores suggest that the majority can co-exist with humans and domestic animals without being implicated in conflicts [31].

Once stakeholders and public are on board, environmental factors regarding timing, area and which Non-lethal repellents to use must be considered to achieve the most successful implementation. Field knowledge and workings of non-lethal deterrents are difficult to attain because studies must occur over larger scales, at which appropriate controls are hard to ensure, replication is difficult and/ or expensive and manipulation can be politically unfavourable [23]. Nevertheless, field knowledge favourably incorporates reality by investigating environmental and ecological factors affecting depredation tools [23]. Unfortunately, due to the unpredictability of factors affecting application, non-lethal deterrent use has to be flexible and adaptable, with no set method achieving success in all scenarios' [4, 27].

Habitat loss, degradation and fragmentation generally lead to an increase in human wildlife conflicts, causing depredation to be frequent or even a dependent habit in areas of Europe where Wolves are more commonly found in urban or otherwise degraded habitats [29, 34, 48]. Decline in wild herbivores results in livestock, livestock carrion and human refuse becoming an important prey source [29, 31, 48]. Wolves prefer to consume wild prey and restoration of wild ungulates can greatly decrease tendencies and need to predate livestock [29, 31, 34]. Habitat management, with forests managed to provide a variety of successional stages with sustained and abundant food supplied throughout the year should minimize problems [30, 45, 50]. There is relatively little livestock depredation in areas where populations of wild ungulates are healthy; however Wolves and dogs are often involved in conflicts fatal to the dog [48].

Wolf attacks upon livestock are affected by fluctuations in environment and changes in pack dynamics. In Western North America it was found that Wolf attacks occurred with seasonal patterns, reflecting seasonality of livestock calving, grazing practices and seasonal variation in energetic requirements of Wolf packs [51]. Predation is generally found to be highest when sheep arrive on summer ranges, coinciding with low rodent populations and pup weaning [24, 48]. Many have found livestock predation to be highest during the denning season when energetic needs are higher [34, 52]. Climactic variation and changes in rainfall have been found to directly correlate with depredation rates; affecting vegetation cover used during hunting and ungulate prey stocks [24, 29, 34]. Conversely, Wolves are more successful predators during periods of high snow cover, with deep snow coinciding with a decline in the condition of juvenile prey [54, 64], possibly signifying more successful predation of wild ungulates and a waning need to predate livestock. It is crucial that management programmes acknowledge these fluctuations, perhaps altering repellent intensities and focusing stronger management during periods of higher depredation. Supplementary feeding could be used during times of high depredation to alleviate pressure, however Wolves have been known to cache surplus food [30].

Environmental factors need to be combined with site and farm factors in order to fully understand and predict susceptibility and appropriate management measures. Less than one percent of livestock producers within Wolf territories experience losses to Wolves each year [48]. It is only a few hot spot sites that experience most of the losses [2, 48]; management programmes should target the factors that make these sites susceptible. Untended livestock in remote pastures, far from human settlements with high levels of peripheral vegetation cover appear to be highly susceptible [31, 35, 48, 52]. It would be advisable to plan the development of human structures and activities away from areas frequented by large carnivores [50]. It is thought that non-lethal techniques are impractical over extended areas with rough terrain and cover, especially when protecting large herds [24].

Domestic stock, via man's selection against "wild" behaviour has led to riches of clustered, unfit and generally dim-witted prey accessible to opportunistic carnivores [31]. It is not surprising that Wolves take advantage of this bountiful easy prey. Wolves generally attack young Cattle, Horse and Reindeer [48]; in contrast Wolves appear to select adult Sheep and Goats [53]. Predation of stock is affected by breed, stock management and preys previous experience with predators [31]. The dynamics of animals contained within pastures may also factor into depredation rates, and are important factors to be considered during management design, Husbandry practices abandoned in many parts of the world, can easily be adapted with better knowledge in order to decrease depredation [23, 31]. Investigations such as those carried out by Bradley and Pletscher (2005) and Treves et al (2004) assessing factors affecting depredation are exceedingly useful when designing a management plan [46, 52].

There are currently a wide range of non-lethal methods which have been developed to limit predation upon livestock. Regrettably, many have practical limitations and are unlikely to be widely applicable [30]. It is therefore important to incorporate a range of methods in an adaptable management scheme in order to achieve greatest success [31]. Non-lethal methods which alter individuals behaviour, such as conditioned taste aversion, electric shock, sound, light and chemical repellents and diversionary feeding could be successfully used [31] in accordance with one another or in alternation depending upon the environmental factors affecting Wolves behaviour. The repellents showing success in this experiment could be successfully used in the field, but would likely achieve more success if used in accordance with other methods [29, 31].

Improvements to or reinstatement of traditional livestock husbandry practices from where they have been abandoned [23] would be a good basis for any management plan. The proper removal of carcasses, management of birthing dates (either through drug use or appropriately timed introduction of rams or bulls etc… to flocks) thus limiting exposure of young, herding vulnerable animals at night, combining herds as to not spread livestock across pastures and contained birthing of young [23, 24, 29, 30, 31, 34] are but a few husbandry techniques that help protect vulnerable livestock and limit depredation. key husbandry practice commonly used in many parts of Europe and by Native Americans, is the use of guard animals, whether these are dogs, llamas or even human shepherds; guard animals have been widely used and successful [31, 34, 35, 48]. However, such guards are not affordable to all and not effective in all scenarios [24, 29]. Ten percent of guard dogs have been shown to harass or kill livestock as well as harassing wildlife [24].

The use of rubber bullet guns could be a useful supplementary tool that may help condition wolves not to approach farms and livestock [28, 50]. These non-lethal guns are not very accurate and don't shoot far, ideally Wolves are conditioned but if nothing else, livestock owners have some control of their situation and receive a psychological benefit of being able to actively protect their livestock [28]. This is useful in promoting positive stakeholder attitudes and acceptance of Wolves [28]. Similarly if stakeholders and local community members are involved in the process, trans-location of problem Wolves can help acceptance and mitigate depredation. Trans-locations are sadly often ineffective, creating space for new livestock predators or with homeward migration of problem individuals whom if trans-located too far away to return home may cause conflicts in the translocation site [6, 27, 31]. Fertility control is another such option [6, 23, 31].

Compensation schemes reimbursing farmers for livestock losses due to carnivores although not reducing depredation, can be used in concurrence with protection methods to increase acceptance and relieve economic stress caused by carnivores [6, 31]. Compensation schemes have shown success in decreasing illegal culling of wild carnivores, as has been the case in Kenyan Masailand with reimbursements for livestock lost to Lions [55]. Unfortunately there are problems with compensation schemes involving false claims and a lack of public support for money to be used in such a way [31], such schemes need to be implemented cautiously.

Excluding Wolves from livestock areas using fencing is useful if livestock are not free roaming [29]. The type of fencing used depends upon locally available materials [29, 43]. Improving traditional fencing with electric wires significantly prevent attacks [29, 35, 56] although this may not always be economically viable and may isolate other wild populations hindering movement [29, 43].

Scare devices and psychological barriers such as those shown to have some success in this experiment could be used in an integrated plan to help strengthen defences against depredation. They are not without their problems in the field though. There are concerns over fladry's field application; over a large scale high levels of maintenance will likely be needed to reposition wrapped flags and to replace those removed by cattle [29]. Turbo fladry is an improved electrified fladry that may provide conditioning as well as aversive stimuli [57]. No signs of habituation were seen towards successful repellents in this experiment, yet the risk of habituation is still expected to be strong when repellents are applied in the field; stimulants must remain novel or be extremely aversive in order to delay habituation [24, 25, 27, 28, 29, 30, 31, 32]. Time till habituation is likely related to the frequency at which Wolves visit farms [32]. Many scare devices would likely work better if activation of the disruptive stimuli were triggered by predator behaviour such as Motion activated guards or electronic radio activated shock collars worn by the Wolves which can be activated by sensors or the sounds of bells worn by free ranging livestock [24, 25, 27, 28, 29, 30, 32].

Olfactory repellents such as silent roar used in this experiment could also be implemented into depredation management, but are expected to work only in combination with actual aversive conditioning [24]. Chemical compounds can be used to mimic the scent marks of conspecifics, acting as a deterrent [30]. Pepper spray (capsaicin) was found to be effective at less than thirty feet against black bears [50], so motion activated pepper sprayers could be useful also. It has even been observed that human urine or ammonia mixed with bait has been effective against bears [58]. It is thought that similarly to physical repellents, habituation would be a problem [30]. Conditioned taste aversion may offer a more permanent solution [6, 30]. Similarly auditory deterrents have shown success, such as electronically synthesised aggressive Polar bear roars [56].

Successful livestock protection requires the implementation of new and traditional methods that best compliment and adapt to each situation [25]. Wolf control is only generally employed as a short term response to depredation [51]; long term plans are needed in order to manage conflicts properly. The short lived nature of many deterrents is a major problem, there is need for multiple simultaneous defences, and rotational tool use carried out selectively depending upon situation [31]. Successful strategies will be based on the integration of many disciplines [31], with human, environmental and site specific factors taken into account throughout implementation and planning.

Non-lethal techniques require significant time and often initial expense, which is why it is important to find affordable successful methods as lethal control is cheap and requires little labour [24]. Lethal control may however sill have use as a last resort in management schemes, if it can be applied selectively to reduce future conflicts and only remove problem carnivores [43]. Human ingenuity has yet to resolve human carnivore conflicts regarding depredation [48], surprisingly few examples exist of rigorous large scale field experimentation [32]; in order to achieve successful non-lethal management this needs to be addressed.

Relevance for carnivore reintroduction programmes

Wolves are re-colonising many areas of Europe but will not be able to recolonize the UK without human interference [59, 60]. It is proposed that the Scottish highlands have the potential to support a viable Wolf population due to low human population, and a high density of wild ungulates [61, 62]. Although Wolves prefer wild prey, livestock depredations are documented and it is of worry and a main point of opposition to re-introductions [61, 62]. Public attitudes are positive yet stakeholders including many livestock farmers have fears over depredation [62, 63]. Non-lethal repellents and schemes such as compensation, if implemented could aid the acceptance of re-introduction programmes and encourage the support of local people and stakeholders. It is important that proper protection methods are put into place before re-introducing Wolves onto a landscape from which they have been absent.

Evaluation and conclusions

Although data sets were small giving low degrees of freedom hindering statistical viability, the experiment gives evidence and inclinations towards the potential of the disruptive stimuli tested. However, the results are not applicable to all Wolves or even Wolves in the wild as the experiments were carried out upon captive Wolves (although this is not necessarily a bad thing as they are likely less fearful of human objects than their wild counterparts [4]). There have been surprisingly few rigorous field tests of non-lethal management tools conducted on a large scale [32]. Adoption of non-lethal approaches depends upon proof of their success [30], in order for acceptance of non-lethal tools there is great need for replicated experimental manipulations to identify the relative benefit of particular management practices [30, 48]. Integrated tests where tools are combined would be interesting, but would require active participation of farmers [57]. Unfortunately one casualty in the field usually ends up with farmers abandoning test protocol, making it hard to ascertain repellents true effectiveness [22].

This experiment could be advanced by testing repellents in combination and for a longer testing period to fully establish the extent of habitual behaviour. The aversive strength of stimuli could be further tested by attempting to protect food sources using repellents; although this would be difficult and potentially dangerous to handlers. Testing under varying weather conditions would be useful to understand the effects of weather upon the efficiency of repellents. Ideally if a similar experiment were to be carried out testing further repellents, more than one observer would be useful for observations of group responses. Wolves tested in groups showed very different behaviours, and although these were observed the results were quantified as one response. Observers would have to follow strict guidelines for consistency. Further experiments with varying pack sizes and age compositions would be useful in understanding how these factors impact success. Experiments in the field with wild Wolves would be ideal, however controlled experiments are complicated; the number of spatial and temporal variables involved make tests difficult to design [48]. Repellent use and management schemes can be made more effective by understanding the conditions under which wolves prey upon livestock [34]; experiments such as those carried out by Treves et al (2004) predicting the effects of landscape and environmental variables are highly valuable [46].

It is important from the outset to dispel hopes for "Silver bullet" strategies as they are highly unlikely [45]. There is usually no singly effective solution, to manage depredation many different techniques are necessary because every situation is unique; adaptive, situation adjustable management is best [28, 29, 48]. Every non-lethal tool should be examined, developed and made economical, increasing chances of finding the right tool for a particular scenario [28]. Change in human attitudes [29] can be achieved through pro-active co-management plans and stakeholder involvement [32, 45, 47]. Innovation and imagination are required to find solutions to conflicts, most likely requiring a mixture of strategies [31].

"Stakes can be high in human wildlife conflicts, theoreticians and field researchers should study the politics and measure the socio-political acceptance of proposed management before implementation and then disseminate the results efficiently to wildlife managers and policy makers" [65]. Only once human, environmental, carnivore and site specific factors are taken into account can an adaptable management plan be implemented and conservation of large carnivores achieve success. It is of utmost importance to keep striving to discover and test the effectiveness and field application of non-lethal depredation controls if large carnivores and humans are to co-exist peacefully.

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Plates

- Readings C (2008) *Plate 1: Mai and Me. Showing the level of familiarity with the test subjects*
- Readings C (2008) *Plate 2: Mosi*
- Readings C (2008) *Plate 3: Duma and Dakota*
- Readings C (2008) *Plate 4: Torak and Me. Showing familiarity with test subjects.*
- Google Imagery (2006) *Plate 5: The UK Wolf Conservation trust (test site)* Adapted from: Allison-Hughes V (2008) *An investigation into the possibility of self-medication using common herbs in captive Wolves (Canis lupus)* BSC (Honours) degree: Animal Science and Management, The Royal Agricultural college, Cirencester UK

Appendix A: Raw Data

Group	Week	Behav	Pprop	Stim	ArcP
1	1	1	0.3	1	33.21091
2	1	1	0.36	1	36.8699
3	1	1	0.389	1	38.58674
1	1	2	0	1	0
2	1	2	0.52	1	46.14622
3	1	2	0.167	1	24.12046
1	1	3	0.7	1	56.78909
2	1	3	0.12	1	20.2679
3	1	3	0.444	1	41.78469
1	2	1	0.167	1	24.12046
2	2	1	0.143	1	22.21935
3	2	1	0.115	1	19.82306
1	2	2	0.167	1	24.12046
2	2	2	0.107	1	19.09337
3	2	2	0.269	1	31.24188
1	2	3	0.667	1	54.75587
2	2	3	0.75	1	60
3	2	3	0.615	1	51.64854
1	3	1	9999	1	#NUM!
2	3	1	9999	1	#NUM!
3	3	1	9999	1	#NUM!
1	3	2	9999	1	#NUM!
2	3	2	9999	1	#NUM!
3	3	2	9999	1	#NUM!
1	3	3	9999	1	#NUM!
2	3	3	9999	1	#NUM!
3	3	3	9999	1	#NUM!
1	4	1	9999	1	#NUM!
2	4	1	9999	1	#NUM!
3	4	1	9999	1	#NUM!
1	4	2	9999	1	#NUM!
2	4	2	9999	1	#NUM!
3	4	2	9999	1	#NUM!
1	4	3	9999	1	#NUM!
2	4	3	9999	1	#NUM!
3	4	3	9999	1	#NUM!
1	5	1	9999	1	#NUM!
2	5	1	9999	1	#NUM!
3	5	1	9999	1	#NUM!
1	5	2	9999	1	#NUM!
2	5	2	9999	1	#NUM!
3	5	2	9999	1	#NUM!
1	5	3	9999	1	#NUM!
2	5	3	9999	1	#NUM!
3	5	3	9999	1	#NUM!
1	6	1	9999	1	#NUM!
2	6	1	9999	1	#NUM!
3	6	1	9999	1	#NUM!

Key

BEHAVIOURS
1=Inquisitive
2=Fearful
3=Oblivious

Stimuli disruptor
1= Bell
2=Flagging
3=Wind Chimes
4= Cd's
5=Silent roar

Groups
1=Mosi and Mai
2=Duma and Dekota
3= Torak

9999 Missing Values

1	6	2	9999	1	#NUM!
2	6	2	9999	1	#NUM!
3	6	2	9999	1	#NUM!
1	6	3	9999	1	#NUM!
2	6	3	9999	1	#NUM!
3	6	3	9999	1	#NUM!
1	1	1	0.4	2	39.23152
2	1	1	0.25	2	30
3	1	1	0.2	2	26.56505
1	1	2	0.35	2	36.2712
2	1	2	0.563	2	48.61925
3	1	2	0.8	2	63.43495
1	1	3	0.25	2	30
2	1	3	0.188	2	25.69559
3	1	3	0	2	0
1	2	1	0.257	2	30.46099
2	2	1	0.174	2	24.65372
3	2	1	0	2	0
1	2	2	0.628	2	52.41642
2	2	2	0.826	2	65.34628
3	2	2	1	2	90
1	2	3	0.115	2	19.82306
2	2	3	0	2	0
3	2	3	0	2	0
1	3	1	0.08	2	16.42994
2	3	1	0.391	2	38.7042
3	3	1	0	2	0
1	3	2	0.52	2	46.14622
2	3	2	0.457	2	42.53323
3	3	2	1	2	90
1	3	3	0.4	2	39.23152
2	3	3	0.152	2	22.94652
3	3	3	0	2	0
1	4	1	0	2	0
2	4	1	0.4	2	39.23152
3	4	1	0	2	0
1	4	2	0.103	2	18.71955
2	4	2	0.44	2	41.55395
3	4	2	0.545	2	47.5818
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2	4	3	0.12	2	20.2679
3	4	3	0.455	2	42.4182
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2	5	1	0.468	2	43.16528
3	5	1	0.208	2	27.13381
1	5	2	0.782	2	62.16644
2	5	2	0.238	2	29.19953
3	5	2	0.292	2	32.70885
1	5	3	0.094	2	17.8541
2	5	3	0.298	2	33.08576
3	5	3	0.5	2	45
1	6	1	0.25	2	30

2	6	1	0.488	2	44.31238
3	6	1	0.27	2	31.30645
1	6	2	0.35	2	36.2712
2	6	2	0.372	2	37.58358
3	6	2	0.73	2	58.69355
1	6	3	0.4	2	39.23152
2	6	3	0.14	2	21.97276
3	6	3	0	2	0
1	1	1	0.32	3	34.4499
2	1	1	0.357	3	36.69068
3	1	1	0.172	3	24.50224
1	1	2	0.48	3	43.85378
2	1	2	0.405	3	39.52361
3	1	2	0.241	3	29.4009
1	1	3	0.2	3	26.56505
2	1	3	0.238	3	29.19953
3	1	3	0.586	3	49.95206
1	2	1	0	3	0
2	2	1	0.205	3	26.9215
3	2	1	0	3	0
1	2	2	0.75	3	60
2	2	2	0.513	3	45.74493
3	2	2	0.894	3	70.9995
1	2	3	0.25	3	30
2	2	3	0.282	3	32.07553
3	2	3	0.105	3	18.90724
1	3	1	0.267	3	31.11252
2	3	1	0.326	3	34.81748
3	3	1	0.056	3	13.6885
1	3	2	0.5	3	45
2	3	2	0.478	3	43.73909
3	3	2	0.777	3	61.82093
1	3	3	0.233	3	28.86194
2	3	3	0.196	3	26.27748
3	3	3	0.167	3	24.12046
1	4	1	0.429	3	40.9182
2	4	1	0.167	3	24.12046
3	4	1	0	3	0
1	4	2	0.314	3	34.08049
2	4	2	0.6	3	50.76848
3	4	2	0.5	3	45
1	4	3	0.257	3	30.46099
2	4	3	0.233	3	28.86194
3	4	3	0.5	3	45
1	5	1	0.326	3	34.81748
2	5	1	0.375	3	37.76124
3	5	1	0.176	3	24.80451
1	5	2	0.326	3	34.81748
2	5	2	0.531	3	46.77731
3	5	2	0.265	3	30.98285
1	5	3	0.347	3	36.09083
2	5	3	0.094	3	17.8541

3	5	3	0.559	3	48.38835
1	6	1	0.214	3	27.5551
2	6	1	0.63	3	52.53503
3	6	1	0.093	3	17.7557
1	6	2	0.643	3	53.30932
2	6	2	0.37	3	37.46497
3	6	2	0.548	3	47.75444
1	6	3	0.143	3	22.21935
2	6	3	0	3	0
3	6	3	0.389	3	38.58674
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3	1	3	9999	4	#NUM!
1	2	1	0.4	4	39.23152
2	2	1	0.205	4	26.9215
3	2	1	0	4	0
1	2	2	0.6	4	50.76848
2	2	2	0.513	4	45.74493
3	2	2	1	4	90
1	2	3	0	4	0
2	2	3	0.282	4	32.07553
3	2	3	0	4	0
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2	3	1	0.314	4	34.08049
3	3	1	0.385	4	38.35146
1	3	2	0.516	4	45.91689
2	3	2	0.143	4	22.21935
3	3	2	0.616	4	51.70742
1	3	3	0.291	4	32.64581
2	3	3	0.543	4	47.46677
3	3	3	0	4	0
1	4	1	0	4	0
2	4	1	0.167	4	24.12046
3	4	1	0	4	0
1	4	2	0.429	4	40.9182
2	4	2	0.143	4	22.21935
3	4	2	0.733	4	58.88748
1	4	3	0.571	4	49.0818
2	4	3	0.69	4	56.16684
3	4	3	0.267	4	31.11252
1	5	1	0.534	4	46.94956
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3	5	1	0	4	0
1	5	2	0.276	4	31.69228
2	5	2	0.364	4	37.10834
3	5	2	0.421	4	40.45459

1	5	3	0.19	4	25.84193
2	5	3	0.152	4	22.94652
3	5	3	0.58	4	49.60345
1	6	1	0.412	4	39.93157
2	6	1	0.297	4	33.0231
3	6	1	0.143	4	22.21935
1	6	2	0.415	4	40.10609
2	6	2	0.141	4	22.0552
3	6	2	0.19	4	25.84193
1	6	3	0.18	4	25.10409
2	6	3	0.563	4	48.61925
3	6	3	0.667	4	54.75587
1	1	1	9999	5	#NUM!
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3	2	1	0.167	5	24.12046
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2	2	2	0.48	5	43.85378
3	2	2	0.834	5	65.95645
1	2	3	0.31	5	33.83316
2	2	3	0.12	5	20.2679
3	2	3	0	5	0
1	3	1	0.3	5	33.21091
2	3	1	0.536	5	47.06443
3	3	1	0.071	5	15.45362
1	3	2	0.65	5	53.7288
2	3	2	0.321	5	34.51129
3	3	2	0.571	5	49.0818
1	3	3	0.05	5	12.92097
2	3	3	0.143	5	22.21935
3	3	3	0.357	5	36.69068
1	4	1	0.487	5	44.25507
2	4	1	0.196	5	26.27748
3	4	1	0.182	5	25.2529
1	4	2	0.359	5	36.8102
2	4	2	0.275	5	31.62816
3	4	2	0.818	5	64.7471
1	4	3	0.154	5	23.10568
2	4	3	0.529	5	46.66251
3	4	3	0	5	0
1	5	1	0.615	5	51.64854
2	5	1	0.559	5	48.38835
3	5	1	0.115	5	19.82306
1	5	2	0.384	5	38.29258

2	5	2	0.176	5	24.80451
3	5	2	0.385	5	38.35146
1	5	3	0	5	0
2	5	3	0.265	5	30.98285
3	5	3	0.501	5	45.0573
1	6	1	1	5	90
2	6	1	0.5	5	45
3	6	1	0.135	5	21.5568
1	6	2	0	5	0
2	6	2	0.5	5	45
3	6	2	0.486	5	44.19775
1	6	3	0	5	0
2	6	3	0	5	0
3	6	3	0.378	5	37.93863

Appendix B: Experimental notes

Mai and Mosi:

07/08/08

Cd's and lion scent (silent roar) were not tested in the first week due to time constraints.

Weather conditions: Cloudy, Overcast, humid, not much wind.

Bell:

Notes: Generally unfearful, Mosi even went to walk through the fence. Some scent marking probably due to the other wolves. Mosi made contact with the fence.

Flagging:

Notes:

Touch	Grab
0	1

Wolves skirted round the fence, Mai the Alpha wouldn't go near it. Wolves occasionally sniffed at the flags and made squeek like noises.

Wind chimes:

Notes:
The fence was generally avoided, however Mosi made contact with the fence but backed off when a noise was created by the chimes.

Touch	Grab
4	0

13/08/08

Mosi and Mai had already been out for a walk in the woods earlier in the day.

Weather conditions: Slight wind and overcast

Bells:

Notes:
Very little attention to the bells which have shown to have almost no effect in most of the wolves.

Flagging:

Notes: The wolves were licking their lips showing timidness, Mosi was startled by the movements of the flags after she grabbed them. Both wolves were spooked by the movements of the flags.

Touch	Grab
0	2

Wind Chimes:

Notes:
Wouldn't really go near the fence.

CD's:

Notes:
Wouldn't go near the fence after the wind blew and moved the cd's creating a sound. Before this however Mosi was inquisitive and grabbed pone of the cd's.

Touch	Grab
0	1

Silent Roar:

Notes:
Stayed well away from the fencing, and frequently smelled the air.

18/08/08

Weather Conditions: Windy, Cloudy, slight rain.

Flagging:

Notes: The wolves didn't stay near the fence for long, whimpered occasionally.

Wind chimes:

Notes: Mai was still wary but beginning to investigate more. Mosi was generally moving away form the fences more quickly and paying less interest. Still generally avoiding.

Cd's:

Notes:
Unlike previous tests, Mai the Alpha female was the first to approach and investigate the fencing

Silent roar:

Notes:
Smelt the air a lot but walked away from the fence after only a short time.

26/08/08

Weather conditions: Overcast, no wind, pale clouds, light but not sunny

Flagging:

Notes: Wolves were distracted by something happening elsewhere at the trust.

Wind Chimes:

Notes: Mai was wary and would rarely glance at the fencing but then gave up interest and caught a mouse nearby instead. Mosi was very inquisitive but not scared or wary.

Cd's:

Notes: Mai general avoided the fencing giving it wary glances.

Silent roar:

Notes: Mai stayed away and wasn't very interested, she was also whining. Mosi made contact with the scented bags.

Touch	Grab
2	6

03/09/08

Weather conditions: Clear sky, sunny with a slight wind.

Flagging:

Notes: Mai was very spooked by the flagging, tail was tucked, ears were back and she wouldn't go near the fencing. Mosi was also slightly wary and generally avoided the fence.

Wind Chimes:

Notes: Mosi was inquisitive however for only a short time. Mai was wary and skirted around the fence. Not too much interest was paid to the fence even when sounds occurred.

Touch	Grab
6	4

Cd's:

Notes: Mai paid little attention to the fence, however Mosi was very inquisitive and seemed to enjoy playing with the fence and was insistent on grabbing and pulling at the Cd's. This may have been due to the reflectivity of the Cd's shining in the sunlight.

Touch	Grab
13	24

Silent roar:

Notes:. Mosi was very inquisitive, sniffing the air a lot and had to be restrained from walking through the fence. Mai stayed at a

2	4
Touch	Grab

distance.

11/09/08

Weather Conditions: Light but still not sunny. Mild with a slight breeze.

Flagging:

Notes: Not too much interest was paid however they still skirted the fence and didn't really approach it.

Wind Chimes:

Notes: Mosi spent more time than Mai. Near the fencing although still didn't spend much time near the fencing.

Touch	Grab
1	0

Cd's:

Notes: The wolves were not really wary at all, Mai went closer than before. Mosi when spooked went straight back up to the fence afterwards. All fear lost by Mosi.

Touch	Grab
2	2

Silent roar:

Notes: Wolves sniffed the air a lot. Mosi grabbed one of the bags and broke the fence.

Touch	Grab
1	1

Duma and Dakota:

07/08/08
Cd's and lion scent (silent roar) were not tested in the first week due to time constraints.

Weather conditions: Cloudy, Overcast, humid, not much wind.

Bell:

Notes:
Wolves Jolted and moved away from fencing.

Flagging:

Notes:
Dakota completely avoided the flagging, even from far away was acting timid and would not approach the fence, it took a long time to get her anywhere near the fence.

Wind chimes:

Notes:
The fence was generally avoided, however the wolves were quite inquisitive and Dakota even made contact with the fence but backed off when a noise was created by the chimes.

Touch	Grab
6	1

13/08/08

Weather conditions: Windy, overcast

Bells:

Notes:
Wolves showed interest and wanted to grab the fence but generally paid no attention to the bells which have shown to have almost no effect in most of the wolves.

Flagging:

Notes:
Dakota won't grab or go near the flags, head held very low and both wolves backing away after movement of flags in the wind.

Wind Chimes:

Notes:
Duma backed away and walked away form the fence. Dakota was intrigued, a little wary but didn't grab or go very close to the fence.

CD's:

Notes:
Not much interest in the CD's, however they did bolt after the wind blew them.

Silent Roar:

Notes:
Dakota was especially intrigued. Spent time sniffing the air and taking in the scent and even tried to taste once.

18/08/08

Weather Conditions: Windy, Cloudy, slight rain.

Flagging:

Notes:
Duma still avoided completely, Dakota was inquisitive and even tasted the flags.

Wind chimes:

Cd's:

Notes:
Very uninterested, got bored after a short time, however Duma did investigate the fencing.

Silent roar:

Notes:
Duma generally avoided and was quite oblivious. Dakota was very intrigued and touched the fence, handlers had to hold her back from the fence quite strongly. The rain may have possibly released more scent.

Touch	Grab
2	3

26/08/08

Weather conditions: Overcast

Flagging:

Notes: Dakota was very inquisitive, Duma spent much less time at the fence. It appears that on most occasions Dakota the lower ranking (Beta) wolf investigates more than the Alpha, Duma. Maybe this is because in terms of the pack she is dispensible so takes more risks ascertaining the danger of the flagging. Dakota made contact with the flags.

Touch	Grab
3	4

Wind Chimes:

Notes: Dakota was backing off quickly after touching or grabbing the chimes often after a noise was caused by grabbing.

Touch	Grab
1	2

Cd's:

Notes: Lost interest very quickly, not paying much attention to the fencing.

Silent roar:

Notes: Dakota was uninterested and just sat down close to the fence.

03/09/08

Weather conditions: Clear sky's however not very sunny, slight breeze.

Flagging:

Notes: Duma avoided looking at the flagging and didn't come too close, also scent marked the area quite a bit, possibly due to the presence of Mosi and Mai's scents. Dakota again made contact.

Touch	Grab
6	6

Wind Chimes:

Notes: Dakota again made contact.

Touch	Grab
4	1

Cd's:

Notes: Duma walked past giving the fencing no attention but still avoided it and stayed at a distance. Again scent marking occurred. Dakota made contact.

Touch	Grab
2	2

Silent roar:

Notes: Duma was spooked by the movement of the bags. Dakota was very intent on trying to grab the bags, not spooked.

Touch	Grab
1	4

11/09/08

Weather Conditions: Light but still not sunny. Slight cloud with light rain.

Flagging:

Notes: Duma was still very wary and timid. Dakota however was very intent on grabbing the fencing and need to be held back very heavily.

Touch	Grab
2	9

Wind Chimes:

Notes: Dakota was snapping at the air.

Touch	Grab
0	10

Cd's:

Notes: Duma wasn't too interested. Both wolves were very oblivious, however a helicopter did pass overhead during this test. Dakota wasn't snapping at the cd's however did try to grab the red ones.

Touch	Grab
0	5

Silent roar:

Notes: Duma was still wary and stand-offish. This test ended swiftly as Dakota was very excitable and pulled and split one of the bags and pulled the fence apart. She sniffed where the scent pellets fell and chewed the bag. She was not spooked when the fence tore apart.

Touch	Grab
0	1

Torak:

07/08/08
Cd's and lion scent (silent roar) were not tested in the first week due to time constraints.

Weather conditions: Cloudy, Overcast, humid, not much wind.

Bell:

Notes: No real reaction to the bells, generally not bothered.

Flagging:

Notes: Torak strongly avoided the fence, minimal eye contact, ears back tail down and didn't come too close but skirted round it.

Wind chimes:

Notes: Torak was at first distracted but not too fearful of the chimes, he did however jolt back after a noise was created and he made contact with the fencing.

Touch	Grab
1	0

13/08/08

Weather conditions: Windy, overcast, slight rain

Bells:

Notes:
Little interest paid, more concerned with following the scent trails left by the female wolves.

Touch	Grab
1	0

Flagging:

Notes:
Very timid, hid behind the handlers and myself, really didn't like the flags.

Wind Chimes:

Notes:
Gave the fence a wide berth and walked past the fencing quickly. He also avoided eye contact with the fence, tail tucked, ears back.

CD's:

Notes:
Left quickly, it was sunnier during this test so this could have had an effect.

Silent Roar:

Notes:
His nose was flairing sniffing at the scent in the air. He was very jumpy with an arched back and tucked tail. Really didn't like the scented bags.

18/08/08

Weather Conditions: Windy, Cloudy, slight rain.

Flagging:

Notes:
Torak was very anxious, his tail begun to tuck and lower as he constantly changed path to avoid the fence, he left its proximity quickly and made little eye contact.

Wind chimes:

Notes: Torak retreated away for the fence cautiously after noise and movement of the chimes.

Cd's:

Notes:
Torak did investigate the fence but left after a short time.

Silent roar:

Notes:
Again generally fearful, I was informed by the head education officer that Torak was giving cut off signals such as licking his lips with an otherwise closed mouth which showed his dislike of the fencing and are intended to cut-off any confrontational action in this case from the fencing.

26/08/08

Weather conditions: Overcast, no wind

Flagging:

Notes: Generally avoided the fence, was wary and stayed at a distance.

Wind Chimes:

Notes: Wary posturing, generally avoided.

Cd's:

Notes: Avoided eye contact with the fence giving the occasional wary glance, still generally avoided it.

Silent roar:

Notes: Gave the fence wary glances.

Torak appears to be spending less time near the fencing as the weeks go on independent of the deterrent being tested.

03/09/08

Weather conditions: Clear sky's however not very sunny, slight breeze.

Flagging:

Notes: Generally avoided however went closer than in previous weeks.

Wind Chimes:

Notes: Toraks ears were generally in a much more confident position than in previous weeks, he came closer to the fencing, however most of the time seemed more interested in the handlers.

Cd's:

Notes: Didn't look directly at the fencing, head was lowered with a few squeeking sounds made.

Silent roar:

Notes: Didn't look directly at the fence, skirted around and did not approach it.

11/09/08

Weather Conditions: Light but still not sunny. Slight wind. Mild

Flagging:

Notes: Torak is still wary of the flagging giving the fencing and flags little eye contact although is starting to show slightly more interest.

Wind Chimes:

Notes: Torak was very distracted by a smell on the grass, perhaps scent of potential prey or scent form one of the other wolves. He was however bolder than before, although became wary after the chimes created sound.

Touch	Grab
1	0

Cd’s:

Notes: Although not making contact with the fence, Torak was little affected by it, the fence seems to have lost its affect.

Silent roar:

Notes: Torak had a short smell at the fence but otherwise skirted around it and avoided it with low eye contact and body posture.

Appendix C: Full ANOVA tables and omitted data

2 way ANOVA tests. Individual repellents. Did arcsine proportions of behaviour change over weeks? Was behaviour towards the repellents non-random?

Group 1

Bells

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	28.153	1	28.153	.184	.710
	Error	306.131	2	153.065[a]		
Behaviour	Hypothesis	1947.520	2	973.760	6.362	.136
	Error	306.131	2	153.065[a]		

a. MS(Error)

Flagging

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	55.053	5	11.011	.028	.999
	Error	3922.503	10	392.250[a]		
Behaviour	Hypothesis	1164.061	2	582.030	1.484	.273
	Error	3922.503	10	392.250[a]		

a. MS(Error)

Wind chimes

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	62.453	5	12.491	.078	.994
	Error	1609.694	10	160.969[a]		
Behaviour	Hypothesis	1103.191	2	551.596	3.427	.074
	Error	1609.694	10	160.969[a]		

a. MS(Error)

Cd's

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	87.380	4	21.845	.063	.991
	Error	2753.208	8	344.151[a]		
Behaviour	Hypothesis	635.810	2	317.905	.924	.436
	Error	2753.208	8	344.151[a]		

a. MS(Error)

Silent roar

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	65.128	4	16.282	.024	.999
	Error	5376.281	8	672.035[a]		
Behaviour	Hypothesis	2943.770	2	1471.885	2.190	.174
	Error	5376.281	8	672.035[a]		

a. MS(Error)

Group 2

Bells

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	.648	1	.648	.001	.977
	Error	1261.920	2	630.960[a]		
Behaviour	Hypothesis	118.702	2	59.351	.094	.914
	Error	1261.920	2	630.960[a]		

a. MS(Error)

Flagging

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	56.264	5	11.253	.070	.995
	Error	1602.851	10	160.285[a]		
Behaviour	Hypothesis	1726.820	2	863.410	5.387	.026
	Error	1602.851	10	160.285[a]		

a. MS(Error)

Wind Chimes

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	58.100	5	11.620	.091	.992
	Error	1280.617	10	128.062[a]		
Behaviour	Hypothesis	1423.781	2	711.890	5.559	.024
	Error	1280.617	10	128.062[a]		

a. MS(Error)

Cd's

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	.909	4	.227	.001	1.000
	Error	1455.677	8	181.960[a]		
Behaviour	Hypothesis	369.803	2	184.901	1.016	.404
	Error	1455.677	8	181.960[a]		

a. MS(Error)

Silent Roar

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	52.336	4	13.084	.061	.992
	Error	1719.511	8	214.939[a]		
Behaviour	Hypothesis	774.075	2	387.038	1.801	.226
	Error	1719.511	8	214.939[a]		

a. MS(Error)

Group 3

Bells

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	.527	1	.527	.004	.954
	Error	249.516	2	124.758[a]		
Behaviour	Hypothesis	447.553	2	223.777	1.794	.358
	Error	249.516	2	124.758[a]		

a. MS(Error)

Flagging

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	61.196	5	12.239	.019	1.000
	Error	6335.928	10	633.593[a]		
Behaviour	Hypothesis	9749.243	2	4874.622	7.694	.009
	Error	6335.928	10	633.593[a]		

a. MS(Error)

Wind Chimes

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	79.838	5	15.968	.058	.997
	Error	2771.253	10	277.125[a]		
Behaviour	Hypothesis	3701.467	2	1850.734	6.678	.014
	Error	2771.253	10	277.125[a]		

a. MS(Error)

Cd's

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	43.609	4	10.902	.014	1.000
	Error	6242.898	8	780.362[a]		
Behaviour	Hypothesis	4363.298	2	2181.649	2.796	.120
	Error	6242.898	8	780.362[a]		

a. MS(Error)

Silent Roar

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Week	Hypothesis	65.446	4	16.362	.051	.994
	Error	2557.127	8	319.641[a]		
Behaviour	Hypothesis	2993.734	2	1496.867	4.683	.045
	Error	2557.127	8	319.641[a]		

a. MS(Error)

2 way ANOVA results. In general (all repellents) did arcsine proportions of behaviour change over weeks? Was behaviour non-random?

Group 1

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Behaviour	Hypothesis	1210.505	2	605.252	1.857	.164
	Error	20855.233	64	325.863[a]		
Week	Hypothesis	28.823	5	5.765	.018	1.000
	Error	20855.233	64	325.863[a]		

a. MS(Error)

Group 2

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Behaviour	Hypothesis	1499.327	2	749.663	4.634	.013
	Error	10354.196	64	161.784[a]		
Week	Hypothesis	55.524	5	11.105	.069	.997
	Error	10354.196	64	161.784[a]		

a. MS(Error)

Group 3

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Behaviour	Hypothesis	16200.828	2	8100.414	22.125	<.001
	Error	23431.207	64	366.113[a]		
Week	Hypothesis	131.554	5	26.311	.072	.996
	Error	23431.207	64	366.113[a]		

a. MS(Error)

Multiple factors ANOVA (all groups, all repellents)

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Behaviour	Hypothesis	9232.593	2	4616.296	5.313	.027
	Error	8774.176	10.098	868.896[a]		
Group	Hypothesis	137.286	2	68.643	4.193	.032
	Error	295.473	18.047	16.372[b]		
Week	Hypothesis	92.301	5	18.460	.034	.999
	Error	1909.630	3.520	542.517[c]		
Behaviour * Group	Hypothesis	7086.556	4	1771.639	5.090	.005
	Error	7134.095	20.495	348.094[d]		
Behaviour * Week	Hypothesis	8801.973	10	880.197	2.515	.038
	Error	7000.802	20	350.040[e]		
Group * Week	Hypothesis	123.600	10	12.360	.035	1.000
	Error	7000.802	20	350.040[e]		
Behaviour * Group * Week	Hypothesis	7000.802	20	350.040	1.460	.102
	Error	38837.860	162	239.740[f]		

a. .982 MS(Behaviour * Week) + .018 MS(Error)

b. .982 MS(Group * Week) + .018 MS(Error)

c. MS(Behaviour * Week) + MS(Group * Week) - MS(Behaviour * Group * Week)

d. .982 MS(Behaviour * Group * Week) + .018 MS(Error)

e. MS(Behaviour * Group * Week)

f. MS(Error)

Effects of various factors upon proportions of fearful behaviour

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Group	Hypothesis	2155.417	2	1077.708	5.002	.029
	Error	2311.776	10.729	215.469[a]		
Stimulant	Hypothesis	4443.977	4	1110.994	9.302	.001
	Error	1672.182	14	119.442[b]		
Week	Hypothesis	4515.269	5	903.054	5.109	.055
	Error	824.042	4.662	176.754[c]		
Group * Stimulant	Hypothesis	1289.454	8	161.182	1.002	.456
	Error	4503.183	28	160.828[d]		
Group * Week	Hypothesis	2181.408	10	218.141	1.356	.251
	Error	4503.183	28	160.828[d]		
Stimulant * Week	Hypothesis	1672.182	14	119.442	.743	.716
	Error	4503.183	28	160.828[d]		
Group * Stimulant * Week	Hypothesis	4503.183	28	160.828	.	.
	Error	.000	0	.[e]		

a. .953 MS(Group * Week) + .047 MS(Group * Stimulant * Week)

b. MS(Stimulant * Week)

c. MS(Group * Week) + MS(Stimulant * Week) - MS(Group * Stimulant * Week)

d. MS(Group * Stimulant * Week)

e. MS(Error)

Factors affecting fearful behaviour to Cd's and silent roar

Tests of Between-Subjects Effects

Dependent Variable:ArcsinP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Group	Hypothesis	1765.144	2	882.572	5.067	.030
	Error	1741.965	10	174.197[a]		
Week	Hypothesis	4.958E8	5	9.915E7	569195.387	.000
	Error	1741.965	10	174.197[a]		
Group * Week	Hypothesis	1741.965	10	174.197	1.735	.148
	Error	1807.170	18	100.398[b]		

a. MS(Group * Week)

b. MS(Error)

This data was omitted from the results section; it was demed too small to derive legitimate analysis and was therefore not appropriate for inclusion. It may however be of interest

Two way ANOVA; Repellent and Exposure effects upon contact with repellents

Tests of Between-Subjects Effects

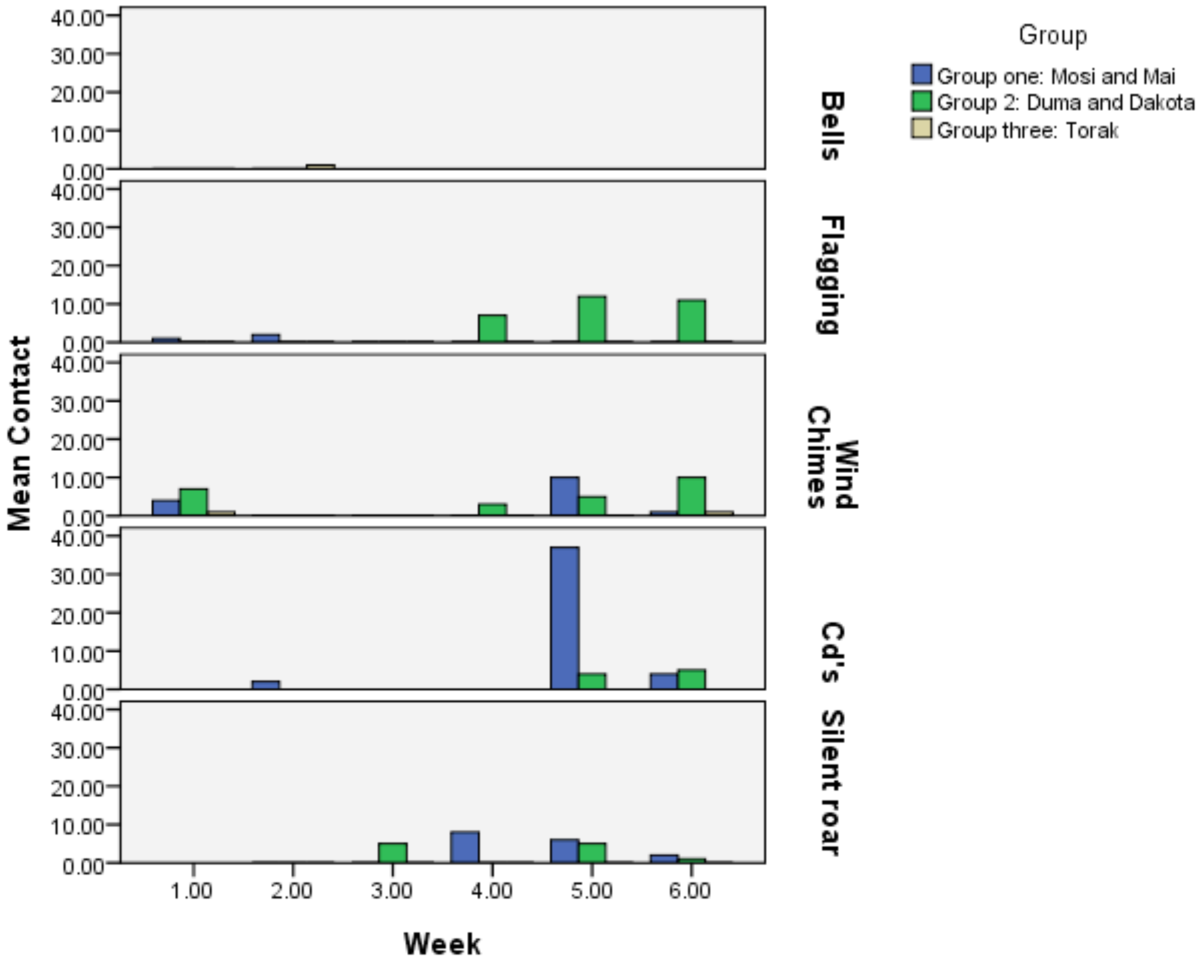
Dependent Variable:Contact

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Repellent	Hypothesis	30.858	4	7.714	.450	.771
	Error	239.781	14	17.127[a]		
Week	Hypothesis	315.019	5	63.004	3.679	.025
	Error	239.781	14	17.127[a]		
Repellent * Week	Hypothesis	239.781	14	17.127	.650	.809
	Error	1264.667	48	26.347[b]		

a. MS(Repellent * Week)

b. MS(Error)

Contact made with fence



The amount of contact groups made with repellents can be seen. It is clear that group three made very little contact with the repellents in general. Statistically (Table 5) the amount of exposure (week) has a significant effect upon contact made with repellents; groups two and three appear to make greater amounts of contact with repellents in the later test sessions. However, only group two made contact with flagging.

Appendix D: Plates (Test subjects and Test site)

Plate 1: Mai and me. Showing the level of familiarity with test subjects.

Plate 2: Mosi.

Plate 3: Duma (left) and Dakota (right)

Plate 4: Torak and Me. Showing familiarity with test subjects.

Plate 5: The UK Wolf Conservation trust (test site)

Enclosure Boundaries =

UK Wolf conservation trust Boundary =

Test area =