Efficacy of an ultrasonic device as a deterrent to dingoes (*Canis lupus dingo*): A preliminary investigation

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Abstract

In April 2001, a nine year old child was attacked and killed by dingoes (*Canis lupus dingo*) on Fraser Island, Queensland, Australia. The Dingo Management Strategy formulated in response to this incident proposed ultrasonic deterrents as one of a number of non-lethal management techniques requiring further investigation. This paper describes a preliminary examination of an ultrasonic deterrent to dingoes using captive animals as subjects. The commercial deterrent unit tested during the study operated at ultrasonic frequencies (24-25KHz). Two units were used simultaneously with one randomly allocated to be operational during each trial. Food lures were placed in front of each unit. Analysis using a Generalised Linear Mixed Model found no significant deterrent effect caused by the unit. Dingoes did show a preference for eating the lure on the right-hand side first, but this was not due to any deterrent effect generated by the ultrasonic units. Limitations associated with the facility where the experiment was conducted, coupled with a restrictive timeframe, meant that the experiment did not achieve as high a level of replication as desired. It did, however, provide an example of how an appropriate experimental design and analytical approach can surmount many of the limitations that can beset small-scale studies.

Keywords: Deterrent, Dingo, Mixed Model, Ultrasound, Wildlife-Human Interaction

Introduction

On April 30, 2001, a nine year old boy was fatally mauled by two dingoes (*Canis lupus dingo*) at the Waddy Point camp ground on Fraser Island, Queensland,

Australia. This tragic incident brought into sharp focus the inherent danger present in certain interactions between humans and wildlife, particularly large predators, and the need to appropriately manage situations where such interactions can occur (Conover 2002). Subsequent to this attack, the Queensland Parks and Wildlife Service (QPWS), the government agency responsible for the management of Fraser Island, formulated the Fraser Island Dingo Management Strategy (FIDMS; EPA 2001). The FIDMS recognised the importance of the Fraser Island dingo population, from both conservation and tourism standpoints, and the congruent needs of preserving dingoes whilst ensuring human safety. As well as highlighting the lack of fundamental ecological knowledge of Fraser Island dingoes and the need for further research in this regard, it also proposed the testing of a variety of non-lethal strategies for limiting and reducing the number of animals loitering around camp sites, resorts and other areas of high human use, and thereby minimising the potential for negative dingo-human interactions. Ultrasonic (i.e. above human hearing range, >20KHz; Stewart 1984) deterrents were identified as one of several aversive and disruptive strategies requiring further investigation (EPA 2001).

A number of studies have investigated the effectiveness of ultrasound as a deterrent in a variety of different species including rodents (e.g. Sprock et al. 1967; Greaves and Rowe 1969; Meehan 1976; Lavoie and Glahn 1977; Shumake et al. 1982), deer (e.g. Curtis et al. 1995; Belant et al. 1998), bats (e.g. Hurley and Fenton 1980; van der Ree et. al. 2002), birds (e.g. Woronecki 1988), kangaroos (e.g. Bender 2001; Bender 2003), domestic cats (e.g. Mills et

al. 2000, Nelson et al. 2006) and domestic dogs (e.g. Blackshaw et al. 1990). As far as can be ascertained, ultrasonic deterrents have not previously been tested on non-domestic canids, in captive or wild situations, although sonic (i.e. within human hearing range, <20KHz; Stewart 1984) deterrents have (e.g. Linhart et al. 1984 (coyotes, *Canis latrans*); Linhart et al. 1992 (coyotes); Breck et al. 2002 (grey wolves, *Canis lupus*)). In almost all of the studies cited above, ultrasonic deterrents demonstrated little capability of causing startle effects or avoidance behaviour in target animals.

Reviews of audiogenic (i.e. sound based) deterrents by Bomford and O'Brien (1990) and, to a lesser extent, Koehler et al. (1990) have criticised the lack of rigour in the experimental design of many, if not most, ultrasonic experiments. Inadequate replication and pseudoreplication, lack of controls, lack of independence, unaccounted for temporal and spatial variation, and habituation of test subjects were some of the problems identified by Bomford and O'Brien (1990). The present study was designed to assess the effectiveness of a commercially available ultrasonic device on captive dingoes. While greatly constrained in terms of sample size, replication and duration, one of the study's major aims was to address some of these problems and demonstrate the benefits of a more rigorously designed experiment in terms of overcoming limitations, often using very simple and affordable methods, in combination with a flexible analytical technique.

Materials and Methods

The study consisted of trials with captive dingoes, as the logistics involved with a similar approach involving wild individuals was prohibitive. Captive trials were conducted at the facilities of the Dingo Conservation and Education Society of Queensland (DCESQ), Rochedale, Queensland. Four dingoes, two males (Wanji and Eenie) and two females (Dixie and Opal), each individually housed, were used for this experiment. All four pens opened into a communal exercise area, which served as the main experimental area.

As animals often respond to novel objects or situations with elevated wariness (Dugatkin 2003), which in this case could have potentially confounded results specifically pertaining to the dingoes responses to ultrasonic frequencies, it was decided that, prior to conducting the experiment proper, dingoes would need to be familiarised with the researchers and experimental materials (e.g. non-operation units, stands, camera equipment). Five familiarisation sessions were carried out over a period of several weeks. Each session usually lasted between one and two hours in duration, and consisted of researchers interacting with dingoes in the communal exercise area, and, at the same time, introducing dingoes to experimental materials.

A series of pilot assessments were also undertaken to determine the most efficient experimental design. For example, as the experiment was conducted in a relatively large communal exercise area which offered only one point with which to power the ultrasonic units, a considerable area was outside the effective range of the units. Therefore, dingoes needed to be attracted to the

98 deterrent units. After pilot trials of scent-based lures failed to consistently attract
99 dingoes, a food-based lure was chosen. This approach had the additional
100 benefit of ascertaining whether a positive stimulus (food) could outweigh any
101 potentially negative effects of an ultrasonic deterrent. Tinned tuna was chosen
102 as the lure due to its pungent odour. The same brand and flavour was used
103 throughout the experiment. The lure was placed on a small plastic disc
104 connected to a short length of dowel rod which was driven into the ground so
105 that the disc was 5cm above ground level. The underside of the disc was
106 coated with petroleum jelly to prevent ants from gaining access to the food lure.
107

108 The original deterrent unit that was to be used in this experiment was a Weitech
109 Transonic Electronic Yard Protector (TEYP). Measurements taken with a RION
110 NA-20 sound pressure level (SPL) meter using a 1/3 octave filter revealed that
111 when the deterrent units were positioned in a back-to-back configuration (see
112 below), sound from the operating unit could be detected behind the unit, i.e. on
113 the non-operating unit side. As this phenomenon would invalidate the use of a
114 control unit in a two unit trial, a decision was made to replace the TEYP with a
115 different unit. The Weitech Yard and Garden Protector (YGP) was subsequently
116 used during the experiment. Measurements taken using the SPL meter
117 revealed no reflected sound behind the unit. When using a 20KHz filter, the SPL
118 meter gave an average reading of 82dB directly in front of the YGP unit. Units
119 were provided for the duration of the experiment at no cost by Bird Gard
120 Australia. In an effort to gauge the acoustical properties of the unit, an ANABAT
121 II (Titley Electronics Pty. Ltd.), a device designed to detect the ultrasonic calls of

microbats, was utilised (sensu Bender 2003). Through the use of a Zero-Crossing Analysis Interface Module (ZCAIM), the ANABAT was connected to a computer and ultrasonic signals captured and measured using the ANABAT software. The YGP unit was found to produce sound in a very narrow band of frequencies, between 24-25KHz, with a cycle taking only around 100ms. The DCESQ facility was also tested for ambient ultrasonic noise using the SPL meter with a 20KHz filter; however no signal in the meter's operational range was detected. Based upon measurements of its SPL output and confirmation of stable and consistent ultrasonic frequencies, the YGP unit was considered to be appropriate for testing as a potential ultrasonic deterrent.

Two ultrasonic units were mounted separately on purpose-built stands which were placed back to back, enabling both units to be filmed for later analysis. The use of two units simultaneously, one randomly assigned on and one off for each trial was seen as the most expedient way to overcome time and facility-related constraints. The simultaneous presentation of treatments (on) and controls (off) has previously been undertaken in trials with audiogenic deterrents (e.g. Shumake et al. 1982).

Each individual trial proceeded in the following manner: All animals were removed from the enclosure and returned to their individual pens. A coin was tossed to determine which unit would be on and which would be off. Approximately 5g (level teaspoon) of tuna was placed in front of each unit. The animal indicated by a randomised draw was released by an assistant who

remained seated quietly in the doorway of the pen (in an attempt to minimise the influence of observer presence). Notes were made on which lure was eaten first (unit on, unit off, left-hand, or right-hand sides) and whether both lures were eaten as well as any novel behaviours exhibited by an individual during the trial. The trial was considered complete when either both lures had been consumed or after ten minutes had elapsed. The dingo was then returned to its pen. As it was possible for an individual to have consecutive trials due to randomised draws, a ten minute rest period was initiated between such trials in an attempt to prevent a lack of interest. Even when not run consecutively, dingoes failed to approach the experimental area on several occasions. As this was not perceived to be due to the effect of the deterrent unit (given that they never approached within its effective operating range), these trials were aborted. This meant that at the end of the entire experiment a number of mistrials were recorded, and the experiment was no longer equally replicated between individuals. A total of four such mistrials occurred, three involving the female Dixie and one involving the male Eenie, giving a total of 60 usable observations. Trials were conducted over 4 consecutive days, with 16 trials attempted each day (4 per dingo).

Statistical analysis consisted of a Generalised Linear Mixed Model (GLMM), which was employed to compare both within- and between-subject variation in dingo responses. GLMMs are an extension of Generalised Linear Models (GLMs - see McCullagh and Nelder 1989 for a definitive discussion) that have the ability to handle the high levels of correlation that are inherent in

170 hierarchical, longitudinal, and repeated measures data through the introduction
171 of one or more random terms in the linear predictor (Breslow and Clayton 1993;
172 Lee and Nelder 1996; McCulloch 1997; Chen et al. 2003). A series of GLMM
173 models were run in the R statistical software package, version 1.8.1 (R
174 Development Core Team 2003), utilising the `glmmPQL` procedure of the `MASS`
175 library (Venables and Ripley 2002). This procedure attempts to fit a GLMM with
176 multivariate normal random effects in the linear predictor using Penalized
177 Quasi-Likelihood (PQL) as an approximate measure of inference (Breslow and
178 Clayton 1993; Breslow 2003).

179

180 Given the limited number of potential explanatory variables, and the restricted
181 nature of the dataset, the model chosen, using ON as a fixed effect, was
182 considered the most parsimonious (see below for a description of the variables
183 used in the final model). This model tests the hypothesis that the probability of
184 the right-hand food lure being consumed first is affected by which unit was
185 operating. The variables used in the model are described below.

186

187 The response variable used was FIRSTEAT. This was a binary variable where:

188 0 = the left-hand food lure was consumed first

189 1 = the right-hand food lure was consumed first

190

191 The explanatory variable used was ON (fixed effect). This was binary where:

192 0 = the left-hand deterrent unit was operating

193 1 = the right-hand deterrent unit was operating

194

195 The grouping term used was DINGO (random effect), which refers to the
196 repeated measurements taken on each of the four dingoes.

197

198 **Results**

199 The fitted (final) model is as follows:

200

201
$$x = 2.163465 - 0.8877144 \text{ ON}$$
$$\hat{\sigma} = 1.470777$$

202 where:

203
$$x = \ln\left(\frac{\hat{p}}{1 - \hat{p}}\right)$$

204

205 $\hat{p}$ denotes the predicted probability of 'success', and $\hat{\sigma}$ the estimated random
206 effects standard deviation.

207

208 The expression for x can be solved for $\hat{p}$ giving:

209

210
$$\hat{p} = \left(\frac{e^x}{1 + e^x} \right)$$

211

212 This gives the following results:

213

214 For ON = 0, $\hat{p} = 0.9742753$

215 For ON = 1, $\hat{p} = 0.939717$

216 The values given above are probabilities, and therefore range between 0 and 1.
217 A probability less than 0.5 indicates a 'failure', where a failure is defined as 'ate
218 the left-hand side lure first' (FIRSTEAT = 0); while a probability greater than 0.5
219 indicates a 'success', where a success is defined as 'ate the right-hand side lure
220 first' (FIRSTEAT = 1). It should be borne in mind here that success and failure
221 are standard terms used when dealing with binary variables and that no other
222 connotations associated with these terms is implied. The designation of left as a
223 failure and right as a success was purely arbitrary and it could easily have been
224 reversed without altering the resultant interpretation.

225

226 The results of the model can be interpreted as follows. When ON = 0 (i.e. 'left-
227 hand unit operating'), the probability is greater than 0.5, thus a 'success'. When
228 ON changes from 0 to 1 (i.e. 'right-hand unit operating'), the probability is again
229 greater than 0.5, again indicating a 'success'. However it is important to note
230 that ON was not significant ($p = 0.1570$, $\alpha = 0.05$), indicating that the
231 probabilities given above are statistically indistinguishable: the probability of
232 eating the right-hand lure first is the same regardless of which unit is operating.

233

234 While the above interpretation can be considered as the global model, because
235 a GLMM takes into account non-independence in the data there are separate
236 random intercept estimates for each dingo, thus effectively four separate
237 models. Having derived these expected values calculated by the models, they
238 can be compared to the observed values in order to evaluate the performance
239 of the model. The easiest form of comparison is to construct a set of

contingency tables showing where dingoes were expected and observed to go first (i.e. either left or right dependent on which unit was ON) and a simple comparison made based on percentages.

For ON = 0, all four equations have a probability greater than 0.5, indicating that all dingoes would be more likely to go right first, and for ON = 1, three values were higher than 0.5, indicating that three dingoes would be more likely to go right first, but one was lower indicating that one dingo would be more likely to go left first. The predicted values are summarised in Table 1.

The observed values were simply calculated by tallying what side each dingo went to first compared to which side the operating unit was on across the whole experiment. These values are summarised in Table 2.

It can be seen that when the right unit was on (ON = 1), the predicted and observed values are close, with only a 4% skew towards eating the left-hand lure first in the observed values. When the left unit was on (ON = 0) however, the model was less accurate, with a 21% skew towards eating the left-hand lure first.

Discussion

The results of this study demonstrated clearly that the ultrasonic unit assessed was ineffective in deterring the four dingo subjects from eating the proffered food lures. Out of a total of 60 successfully completed trials, both baits were consumed in 57 cases, a total of 95%. Dixie (twice) and Eenie (once) were the

265 only dingoes to eat a single food lure during an individual trial, and on one of
266 these occasions the uneaten lure was on the unit OFF side. This would indicate
267 that, overall, the unit did not produce enough of a deterrent effect to dissuade
268 the dingoes from eating the lures on the unit ON side. Given the criticisms
269 levelled at the analyses commonly used in the ultrasonic deterrent literature
270 (e.g. Bomford and O'Brien 1990), a GLMM was chosen to provide a more
271 robust and appropriate form of statistical analysis for these data (i.e. data that
272 are highly correlated, have unequal variance, and where there is unequal
273 replication between subjects). It should be noted that, given the small number of
274 subjects available for this experiment, the statistical power of a GLMM could be
275 brought into question. However, we are unaware of any power tests that could
276 be employed for GLMMs at this time. That aside, a GLMM is one of the few
277 tests suitable for such data. For example, Generalized Estimating Equations
278 (GEEs) are one alternative, but they are more suited to datasets with large
279 numbers of individuals and a low number of replicates (McCulloch and Searle
280 2001). One of the fundamental problems in many analyses, not only those of
281 ultrasonic deterrent experiments, is the failure to account for correlation
282 between observations, i.e. observations are not independent (Milinski 1997).
283 This lack of independence is commonly referred to as pseudoreplication
284 (Hurlbert 1984; Heffner et al. 1996; Milinski 1997). Independence is a common
285 assumption of many statistical tests which, if overlooked, can invalidate any
286 analyses done in such situations (Rao 1998). While pseudoreplication is a
287 problem under these circumstances, there are methods of dealing with such
288 data. While redesigning the experiment is one option, the most straightforward

method is to use a statistical test that can handle non-independence. GLMMs are one such test (Breslow and Clayton 1993; Lee and Nelder 1996; McCulloch 1997; Chen et al. 2003). One advantage of using such a test is that repeated measures enable a comparison of intra-subject variation. This allows an examination of changes over time, important in detecting behavioural processes such as habituation.

The GLMM model chosen, with ON as a fixed effect, while not yielding statistically significant results, did appear to provide a relatively good fit to the data, as seen by the comparison of observed versus expected values. Overall, the model predicted that regardless of which unit was ON (left or right), the dingoes would eat the right-hand food lure first more than 90% of the time, slightly higher than the observed value of 78%. The ability to break down the model and identify the effect of each subject shows that it was primarily Opal and Wanji, and to a lesser extent Eenie, that drove this trend. Dixie was the only subject in the model to always display a preference for eating the unit OFF side lure first. The probability of her eating the right-hand lure first when the left-hand unit was ON was 63%, while the probability of her eating the left-hand lure first when the right-hand unit was ON was 58% (recall that the probabilities given are always for eating the right-hand lure first (FIRSTEAT = 1), therefore the probability of eating the left-hand lure first is $1.00 - 0.42$). In both cases this was only marginally more than what would be expected by random chance (i.e. 50%) and is therefore not enough to suggest any noticeable deterrent effect generated by the unit, especially given that ON was not significant.

313

314 While it may appear that the preference three of the four subjects (Wanji, Eenie
315 and Opal) showed for eating the right-hand side lure first might be attributable to
316 some effect of the deterrent unit, the cause of this trend was most likely the
317 location of the release points of the individual animals from their respective
318 pens. Opal's release point meant that she had to pass the right-hand unit on her
319 way to the left-hand unit, so not surprisingly she always went to the right-hand
320 side first. Eenie and Wanji displayed some interesting behaviour in that, when
321 released from their pens, they often both chose to walk along the concrete path
322 running along the edge of their pens, rather than walking straight forwards
323 across an open grassed area towards the units. This path-following behaviour
324 often meant that both animals arrived at the right-hand unit first, as the path
325 lead almost directly towards that side. Eenie, and to a lesser extent Wanji,
326 showed a lessening of this path-following in the latter half of the experiment.

327

328 Why both Eenie and Wanji displayed this behaviour is uncertain. It may have
329 been some apprehension due to the presence of strange objects and people in
330 their enclosure that caused them to stay close to their familiar pens which
331 gradually declined as the experiment went on, although this seems unlikely.
332 Both animals generally showed little fear of the units or the stands they were
333 mounted on during familiarisation sessions; rather, they were initially inquisitive
334 about these novel objects. It may have been due to the social contention
335 between these two males. A series of agonistic displays between these males
336 were witnessed throughout the two month period over which the experiment

was conducted. On numerous occasions, both males scent marked nearby bushes after or during a trial. It may be that both were detecting scent trails left by one another on the concrete paths and followed these trails to investigate what the other was up to. Dingoes in the wild have been shown to travel on paths and roads in preference to crossing open ground or moving through thick vegetation (Mahon et al., 1998), which may also provide some explanation for the similar behaviour demonstrated by Wanji and Eenie. Importantly, this bias for going to the right-hand side first was in no way deemed to be due to any effect generated by the deterrent unit.

While this bias for eating the right-hand food lure first was potentially problematic in terms of exploring the efficacy of the deterrent, given the conditions under which the experiment was conducted, there was little could be done to alleviate it. The layout of the enclosure with its various natural features such as gardens, rocks, logs, trees, etc., and restrictive access to a power source meant that the location chosen to site the units was unavoidable. That being said, the right-hand bias in no way invalidates the experiment. On the contrary, the fact that the unit in no way deterred the dingoes from eating the right-hand lure first as often as they did (78%) is evidence of its lack of effectiveness as a dingo deterrent. The right-hand lure operated in 51.7% of trials (n = 31), slightly more frequently than the left-hand unit (48.3%, n = 29). Thus once again there was no evidence that the unit was in any way influencing the dingoes' behaviour. Finally, confidence in the performance of the experiment, the analysis chosen, and the results obtained is bolstered by the

simple fact that dingoes ate both food lures (including the lure on the unit ON side) on all but several occasions.

In addition to providing an initial investigation of the effectiveness of a specific dingo deterrent, this project also attempted to provide an example of how a more rigorous study could be undertaken to assess the efficacy of such a device, in the presence of many potential limitations. The approach taken here demonstrated that, even with limited resources, such an experiment can still be conducted relatively rigorously. While the findings may be constrained due to the small number of dingo subjects available and the necessity to conduct the experiment with captive dingoes, the experiment itself provides useful guidelines as to how appropriate experimental designs and associated analyses facilitate greater confidence in determining the efficacy of such a deterrent.

While not discounting the obvious caution required in interpreting these findings, this study concurs with others that found no measurable deterrent effect (e.g. Lavoie and Glahn 1977; Woronecki 1988; Belant et al. 1998; Mills et al. 2000; Bender 2001; van der Ree et al. 2002; Bender 2003), suggesting that ultrasound may be of little use as a deterrent for dingoes, and focus should now be shifted towards investigations of other potential, non-lethal management techniques.

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Tables and Figures

Table 1 Expected values derived from model

(Percentages in italics are relative percentages calculated across rows)

		FIRSTEAT	
		Left (FIRSTEAT = 0)	Right (FIRSTEAT = 1)
ON	Left (ON = 0)	0 <i>0%</i>	4 <i>100%</i>
	Right (ON = 1)	1 <i>25%</i>	3 <i>75%</i>

Table 2 Observed values from dataset

(Percentages in italics are relative percentages calculated across rows)

		FIRSTEAT	
		Left (FIRSTEAT = 0)	Right (FIRSTEAT = 1)
ON	Left (ON = 0)	6 <i>20.69%</i>	23 <i>79.31%</i>
	Right (ON = 1)	9 <i>29.03%</i>	22 <i>70.97%</i>