Deterrence of kangaroos from agricultural areas using ultrasonic frequencies: efficacy of a commercial device

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Abstract The ROO-Guard® is an ultrasonic device designed to protect agricultural properties from kangaroos (*Macropus* spp.). The manufacturer claims that the signal produced by the ROO-Guard covers a 250-m area, is audible to kangaroos, and results in kangaroos leaving the area. I conducted laboratory and field trials to evaluate these claims. Laboratory trials showed that the ROO-Guard signal had only a small component of ultrasonic frequencies and could be detected using an SPL meter at 70 dB at 50 m. The ROO-Guard did not alter the behavior of captive eastern gray kangaroos (*M. giganteus*) or red kangaroos (*M. rufus*) in any way. The ROO-Guard alone did not reduce the density of free-ranging eastern gray kangaroos at sites where the device was operating as compared to control sites, and I found no change in density with distance from the device. The ineffectiveness of the ROO-Guard should caution against using other ultrasonic deterrent devices, particularly for kangaroos.

Key words acoustic characteristics, agriculture, Australia, behavior, deterrents, eastern gray kangaroo, *Macropus giganteus, Macropus rufus*, red kangaroo, ROO-Guard®, ultrasonic

Abatement of damage caused by wildlife to primary industries is an ongoing challenge throughout the world. The general public is applying pressure for the use of nonlethal methods of control with minimal pain to the animal and high target specificity (Edwards and Oogjes 1998, Reiter et al. 1999). Deterrents are a common nonlethal method to control problem wildlife. Deterrents aim to stop an unwanted behavior or to make the animal retreat from an area using ≥1 sense modalities.

Auditory deterrence devices may use biologically significant or artificial sounds to control problem wildlife. Biologically significant sounds include alarm, distress, alert, or aggressive calls. The purpose of the sounds is to either warn or deter the problem species from feeding, roosting, or loafing sites. These sounds have been used with some success in Europe and North America on birds and predatory mammals (e.g., Smith et al. 2000). Artificial sounds may include a selection of frequencies in the audible, infra-, or ultra-sonic frequency range that have no social or other context (e.g., loud bangs and sirens). Devices that use artificial sounds are available in the United States, Europe, and Australia for species including insects (e.g., Dryden et al. 1989), birds (e.g., Haag-Wackernagel 2000), marine mammals (Jefferson and Curry 1996), and land mammals, including

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marsupials such as possums (*Trichosurus vulpecula*) (e.g., Coleman and Tyson 1994) and wallabies (*M. rufogriseus*) (Statham 1993), and eutherians such as rodents (e.g., Lund 1984) and carnivores (e.g., Linhart et al. 1992). These devices claim to cause pain or fear, jam communication, or disorient, but are generally ineffective or have a short-lived effect. For example, pigeons (*Columba livia*) were not deterred from a vacant building by an audible electronic sound device (Woronecki 1988), whereas coyotes (*Canis latrans*) were deterred from lambs by gas exploders, but only for an average of 31 days (Pfeifer and Goos 1982).

Ultrasonic frequencies are those frequencies above the human hearing range (10 Hz-20 kHz). Ultrasonic frequencies have a short wave length, attenuate rapidly in air and with distance, and are extremely directional (Gould 1983). They have become a popular choice for deterrents because they are said to be humane, cost-effective, easy to use, and scientifically sound (Bomford and O'Brien 1990). Manufacturers of ultrasonic deterrence devices claim that their products deal with a variety of different target species, require little or no maintenance, and the sound produced is inaudible and therefore not irritating to nearby humans. Ultrasonic frequencies are audible to some animals such as dogs, bats, and rodents (Frings and Frings 1967). However, reviews by Bomford and O'Brien (1990), Bomford (1992), and Erickson et al (1992) found no evidence of a reduction in damage to property by birds or mammals.

At least 5 species of large marsupials—the eastern gray kangaroo, western gray kangaroo (*M. fuliginosus*), red kangaroo, red-necked wallaby (*M. rufogriseus*), and swamp wallaby (*Wallabia bicolor*)—are considered pest species by agriculturalists and stockists throughout most of Australia. These species have been implicated in damage to crops and property (e.g., Gibson and Young 1987), competition with livestock for food and water (e.g., Edwards 1989), and alteration of habitat quality (e.g., Coulson 2001).

The ROO-Guard® Mk I was invented in Australia in 1988 by Shu Roo (Sumner Park, Queensland, Australia) Pty. Ltd. A revised version, ROO-Guard Mk II, was released in 1992 and currently is available commercially. Pamphlets and instruction sheets produced by the manufacturer claim that both ROO-Guard versions produce a high-frequency signal that is inaudible to humans. The manufacturers argue that the high-frequency component of the ROO-Guard signal effectively masks the kangaroos' ability to hear their natural predators, making kangaroos uneasy. The ROO-Guard is claimed to have a signal noise level greater than 130 dB, with a sound pattern extending 30–40 m to the front and 125 m to either side of the device.

Statham (1991, 1993) tested the ROO-Guard on wallabies in forestry plantations in Tasmania and concluded it had no effect on wallaby behavior or feeding activity. However, no tests of active sonic devices like the ROO-Guard have been conducted on kangaroos. My objectives were to 1) determine the acoustic characteristics of the signals produced by both models of ROO-Guard, 2) examine the effects of the ROO-Guard signal on the behavior of captive eastern gray and red kangaroos, and 3) evaluate the ROO-Guard's efficacy as a deterrent for free-ranging eastern gray kangaroos.

Methods

I tested 2 models of ROO-Guard: a ROO-Guard Mk I, purchased in 1990, and 4 ROO-Guards Mk II, purchased in 1992. Both models had 4 speakers encased in a metal housing 77 mm wide at the front and 179 mm wide at the back, 242 mm high, and 167 mm deep. Speakers were paired and arranged vertically on the 2 sides of the unit, pointing out at a 45° angle. The Mk I had round speakers that were uncovered; the Mk II had square speakers with vertical slats across them. Both models consisted of a master unit, with signal generator, and slave unit, with speakers only. Master and slave units had the same external appearance.

Acoustical characterization tests

I conducted laboratory tests of the master ROO-Guard Mk I with a fully charged battery in an office without anechoic properties. I made measurements at 1 m on both sides of the ROO-Guard. During post-processing, I determined the signal structure (Eisenberg et al. 1975), frequency bandwidth (maximum minus minimum frequency), signal duration (from the start to the end of one syllable), and inter-pulse duration (from the previous syllable to the subsequent syllable).

I conducted field measurements of the propagation pattern of the ROO-Guard Mk I and Mk II on grass at 2 different sites. I tested the Mk I on an oval on 21 September and 10 October 1994. I tested one of the Mk II units on the same oval in 1995. I took noise-level measurements (dB) every 5 m in the azimuth plane on bearings at 45° intervals, with 0° corresponding to the front of the unit. I tested the second Mk II unit in 2 separate rectangular-shaped paddocks near Bairnsdale, Victoria, in 1997. I took sound-pressure-level measurements in a similar way as for the Mk I (Appendix).

Behavioral response

I measured the behavioral response of captive eastern gray kangaroos and red kangaroos to ROO-Guard Mk I at 2 sites in Victoria: the fauna park enclosure at Royal Melbourne Zoological Gardens (Melbourne Zoo) on 8 and 12 September 1994 and 6–8 February 1995, and the kangaroo enclosure at Werribee Open Range Park on 6–8 March 1995. Prior to testing, the Titley Electronics ANABAT II was used to detect the presence and noise level of frequencies similar to those produced by the ROO-Guard Mk I. Noises that had ultrasonic frequencies were recorded onto a stereo radio cassette recorder (AIWA HS-J380), transmitted to a 486 PC laptop with a ZCAIM, and analyzed with ANABAT software. Noise levels were measured with an SPL meter (B&K 2209).

The fauna park enclosure at the Melbourne Zoo was a 1-ha triangle with a mix of open grass, clusters of native trees and shrubs, and a small dam near the center. A curved pedestrian path through the enclosure ran adjacent to a designated kangaroo sanctuary area separated from the path by a single wood-rail fence. Fourteen eastern gray kangaroos (5 female, 8 male, and 1 young-at-foot) were held in the enclosure. Kangaroos often divided into smaller groups within the enclosure, so a minimum test group size of 5 was set.

I made observations between 0800 and 1000 hours, when kangaroos were often resting close together and few visitors were present. The ROO-Guard was mounted on either a wooden stake or a stand at a height of 1,200 or 1,750 mm, respectively, and powered by a 12-volt battery.

The kangaroos at the Melbourne Zoo were habituated to the presence of humans in their enclosure (Coulson 1997), so we made observations on foot. An assistant placed the master ROO-Guard pointing directly at the kangaroos and as close as possible without causing them to take flight. A trial did not begin until the majority of the kangaroos were in low or nonvigilant postures. A trial consisted of rapidly scanning the kangaroos once with the ROO-Guard either on or off. We ran a minimum of 5 trials each day and continued until at least one off and one on trial was completed per day. The observer wore earplugs to ensure that he or she could not hear the ROO-Guard.

I measured vigilance levels to indicate the behavioral response of captive eastern gray kangaroos to the ROO-Guard Mk I. I recorded the vigilance category of each kangaroo on a scale from no reaction (1) to flight (8), following Croft's (1981) definitions of body postures: kangaroos that were feeding or lying down were considered to be nonvigilant; those that were sitting, crouched, semi-erect, standing erect, or erect alert were considered to be exhibiting increasing levels of vigilance, which corresponded to alarm and ultimately flight.

I recorded onto a hand-held cassette recorder verbal descriptions of the species, group size, sex, and vigilance level of all kangaroos, as well as distance of the observer to each kangaroo. I made observations with 8 × 40 binoculars. If an individual changed location during a scan, it was tracked to avoid recording its response twice. I assumed that a kangaroo's response would be independent on subsequent days.

Werribee Open Range Park tests

The kangaroo enclosure at Werribee Open Range Park was a 4-ha rectangle consisting of an open grass plain with small clusters of trees along the perimeter. Zoo bus tours and maintenance and feeding vehicles regularly traveled through the enclosure. People on foot were not allowed in the enclosure, and bus tours viewed animals from a distance that did not disturb the animals.

Fourteen eastern gray kangaroos (6 female and 8 male) and 17 red kangaroos (6 female and 11 male) were held in the enclosure. There were no young at foot or pouch young in this population, as all males had been castrated. Kangaroos often divided into smaller groups within the enclosure, so I set a minimum test group size of 5.

We made observations between 0900 and 1300 hours, when kangaroos were often resting close together and fewer visitors were present. We used a utility vehicle similar to those used by zoo staff for transport and observations and placed the master ROO-Guard at a point 25–50 m from the kangaroos.

We made observations using the same method described for Melbourne Zoo, except that an assistant and I remained in the vehicle. We measured distance between the kangaroos and the vehicle with either a Sokkisha optical rangefinder (30-cm base) (Sokkisha Co., Ltd., Tokyo, Japan) or a

Lytespeed 400 Laser rangefinder (Bushnell, Overland Park, Kans.). Kangaroo vigilance levels were measured as before.

I used chi-square contingency table analyses to test for patterns in vigilance between treatment (ROO-Guard active) and control (ROO-Guard inactive) trials at both captive sites. I included only the observations from the first inactive and the first active trial for each day in the statistical analyses and used standardized residuals to determine the significance of individual cells in chi-square analyses. The α level for all significance tests was adjusted to 0.01 using the Bonferroni correction for repeated testing.

Free-ranging kangaroo response

We measured the relative density of kangaroos at Yan Yean Reservoir Catchment, southern Victoria, Australia, (145º09′E, 37º32′S) from 5 December 1995 to 21 January 1996. The catchment was situated on the rural fringe of Melbourne, Victoria, in southeastern Australia, 37 km northeast of the Central Business District. The 2,250-ha catchment was closed to the public. The population of eastern gray kangaroos in the catchment was estimated as 2,109 in 1995 by Coulson et al (1999). Female kangaroos at this site have a maximum home-range size of 158 ha (G. Coulson, B. Moore, S. Way, University of Melbourne personal communication). If a circular home range were assumed, the diameter would be 1.4 km.

I tested ROO-Guard Mk II units in 10 randomly selected open grassy areas with a diameter of at least 100 m. Half of the sites were treatment sites with the master ROO-Guard active; the remainder were control sites with the slave ROO-Guard inactive. Treatment and control sites were paired and tested simultaneously to control for weather and other confounding factors. Treatment and control sites were assigned randomly with a minimum distance between sites of 850 m to reduce the likelihood of individuals using more than one site. I tested each site only once.

We mounted ROO-Guard Mk II units on star pickets at 1,750 mm above the ground. At treatment sites, we installed a master ROO-Guard unit with solar panel. At control sites, a mock solar panel and a slave ROO-Guard unit, which was externally identical to the treatment unit, were used. We placed the ROO-Guard at the center of each site with 3 predetermined sound contours based on the propagation pattern of the ROO-Guard Mk II: 60, 45, and

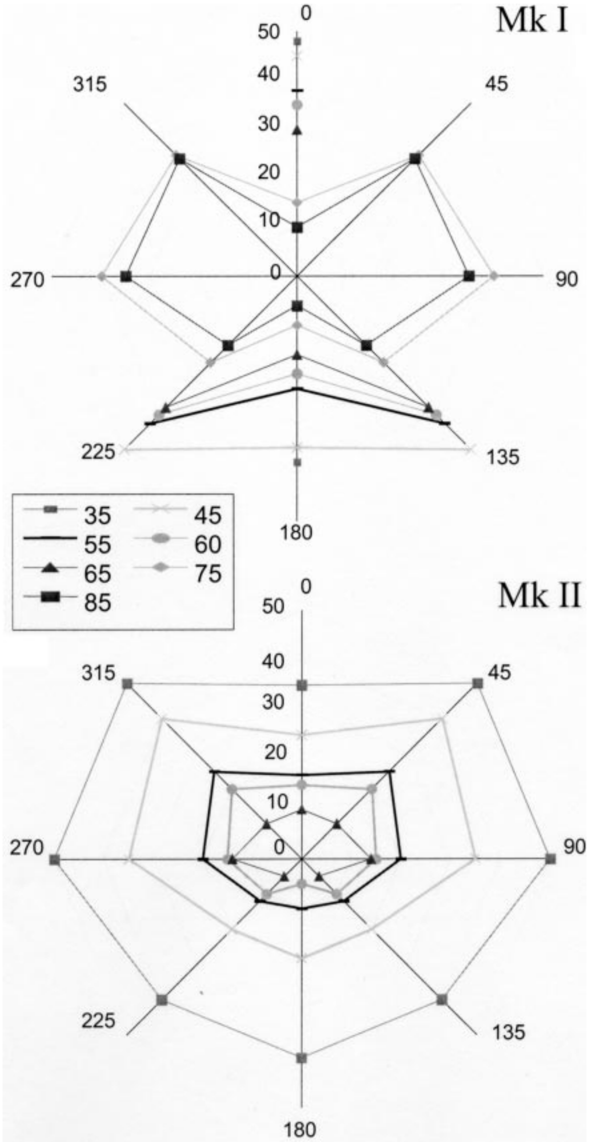

Figure 1. Polar diagrams showing the propagation pattern of the ROO-Guard Mk I and ROO-Guard Mk II signals on grass. The ROO-Guard Mk I was mounted on a stand at 1,750 mm, measured at the University of Melbourne football oval on 21 Sep and 10 Oct 1994 with ANABAT II held at 1,300 mm. The background noise level was 20–30 dB. Measurements of ROO-Guard Mk II were made in Bairnsdale on 8 Dec 1997 with a 20-kHz filter. The ROO-Guard Mk II was mounted on a stand at 960 mm, and the microphone was mounted at 600 mm. The background noise level was 57 dB.

35 dB (Figure 1). The contours represented increasing distance from the ROO-Guard, although the distance from the ROO-Guard changed slightly when the site was located on a slope, extending farther down and contracting up the hill.

Fecal-pellet accumulation was used as an index of kangaroo density (Southwell 1989). We randomly allocated 54 fecal-pellet plots to each site, 17 on the inner, 19 on the middle, and 18 on the outer contour line. Fecal-pellet plots were circular with a radius of 1.78 m, resulting in a 10-m^2 plot. We placed plots on contours by randomly selecting an angle, and any overlapping plots were reallocated. Wooden stakes marked the plots.

Pellet plots were cleared of all fecal pellets prior to testing the ROO-Guard. We counted individual fecal pellets 5–10 days after clearing to allow sufficient time for deposition, but not excessive time in which decomposition of pellets could result (Perry and Braysher 1986, Johnson and Jarman 1987, Southwell 1989).

Fecal-pellet data were cube-root-transformed prior to data analysis to correct for a non-normal distribution. I used a split-plot nested Analysis of Variance (ANOVA) to determine whether differences existed in individual fecal-pellet densities, between treatment and control sites, between sites within a treatment, and across dB contours. I used a Dunett T3 post-hoc test to determine significant differences between sites. The α level for all tests was set at 0.05.

Results

Acoustical characterization tests

Both ROO-Guard models produced a repeating single-syllable signal that was composed of a descending sweep followed by a noisy burst. The syllable can be classified as a Type 1 sound form with descending modulation (sensu Eisenberg et al. 1975). The Mk I signal was variable but ranged from a maximum frequency of 27 kHz to a minimum of 17 kHz (Figure 2). The Mk I signal therefore contained a mix of audible and ultrasonic frequencies, which could be described onomatopoeically as "zip zip." The syllables were long (0.75–0.88 s), and repeated continuously with an inter-syllable duration ranging from 0.12–0.33 s. Hence, syllables were repeated approximately once per second. The signal produced by the Mk II was similar to that of the ROO-Guard Mk I, but its frequency range was consistent and narrower (22.8–15.5 kHz) and the syllable (1.13 s on average) and inter-syllable (0.45 s on average) duration were longer (Figure 2). Therefore, the Mk II also produced a signal of a mix of audible and ultrasonic frequencies, but produced 2 syllables every 3 seconds.

Field noise levels were displayed as polar diagrams to show the propagation pattern of the signals for both ROO-Guard models, with interpolation between points with the same sound level on different bearings to create dB contours (Figure 1). Background noise levels at the football oval ranged from 20 to 30 dB when filtering for 16 kHz and in Bairnsdale were 20.5 dB when filtering for 20 kHz.

The ROO-Guard Mk I signal was loudest to the sides of the unit (90° and 270°) and quietest at the front and back (0° and 180°). The signal was 70 dB at 50 m on the 90° and 270° bearings. The ROO-Guard® Mk II had the greatest noise levels to the sides (45°, 90°, 270°, 315°) and was quietest to the front of the unit (0°; Figure 1). The sound level was 35 dB at 50 m on the 45, 90, 270, and 315° bearings.

Behavioral response

The background noise levels at Melbourne Zoo

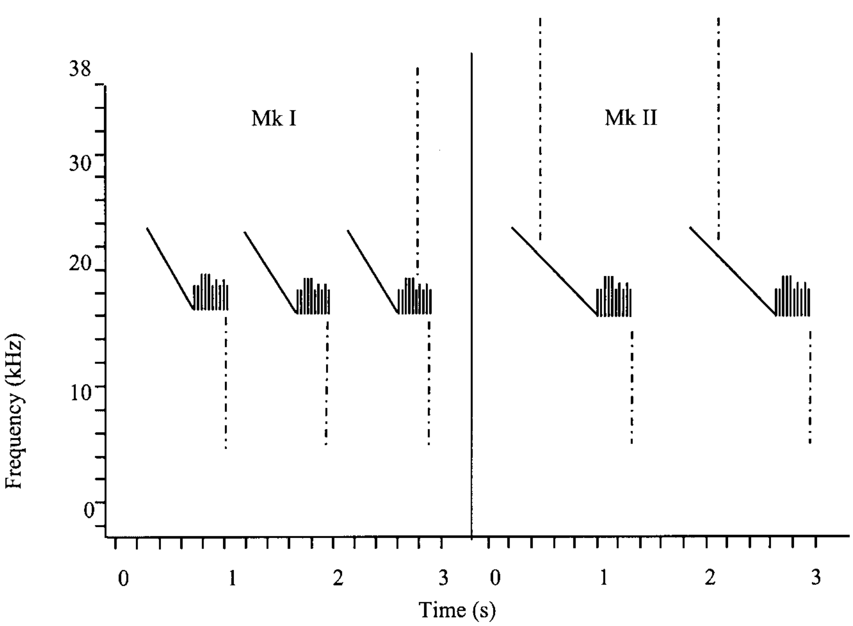

Figure 2. Diagrammatic representation of 3 syllables in the ROO-Guard Mk I and 2 syllables in the ROO-Guard Mk II signals recorded with ANABAT II at 1 m from the device. ANABAT was set with a division ratio of 16, sensitivity of 8.5, and volume of 7.

ranged from 13–33 dB. Ultrasonic frequencies that overlapped with the signal produced by the ROO-Guard occurred at Melbourne Zoo—tram squeals (2.4–22.3 kHz) and dusky moorhen (*Gallinula tenebrosa*) vocalizations (1.90–19.5 kHz, dominant frequencies 5.5–11.5 kHz). The background noise levels at Werribee ranged from 10–13 dB, and I detected no ultrasonic frequencies.

Flight was not observed during any of the behavioral trials with the ROO-Guard on or off. The proportion of eastern gray kangaroos at different vigilance levels did not differ significantly between the ROO-Guard Mk I treatment and control trials at either captive site (Melbourne zoo: $\chi^2_{0.01,4}=0.125$, $P=0.928$; Werribee Park: $\chi^2_{0.01,4}=0.191$, $P=0.782$). Similarly, the proportion of red kangaroos at different vigilance levels did not differ significantly between the treatment and control trials ($\chi^2_{0.01,4}=0.090$, $P=0.953$). However, significantly more gray kangaroos were lying down when the ROO-Guard was off ($\chi^2_{0.01,4}=19.995$, $P=0.001$), whereas significantly more red kangaroos crouched when the ROO-Guard® was on ($\chi^2_{0.01,4}=19.275$, $P=0.001$; Figure 3).

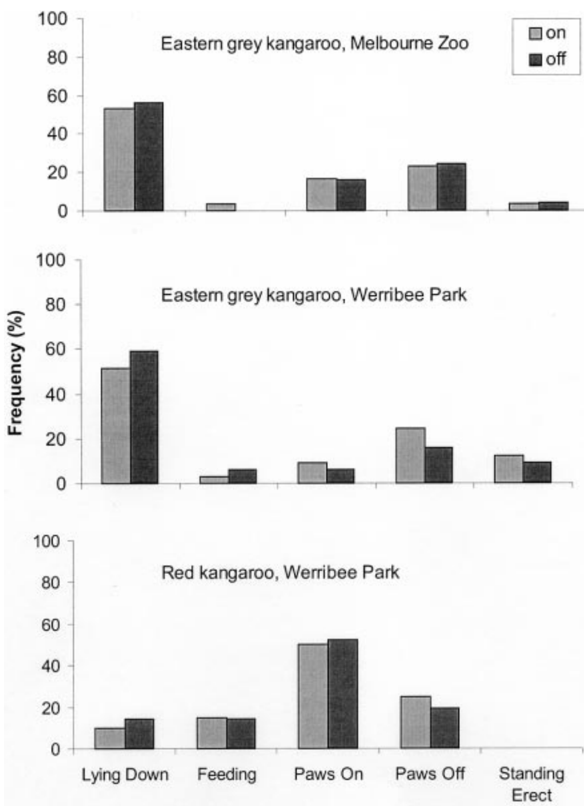

Figure 3. Frequency of nonvigilant and vigilant postures exhibited by kangaroos at the 2 captive sites in response to the ROO-Guard® Mk I. Observations were made on 4 occasions between 8 Sep 1994 and 8 Feb 1995 at Melbourne Zoo, and between 6 and 8 Mar 1995 at Werribee Park, Victoria, Australia.

Free-ranging kangaroo response

The linear background noise levels at Yan Yean Reservoir were 84–106 dB, whereas the 16 kHz filtered noise levels were 36–59 dB. I detected no ultrasonic frequencies.

Fecal-pellet densities did not differ between the treatment and control sites ($F_{1,8}=0.974$, $P=0.353$; Figure 4), suggesting that no significant difference occurred in the relative density of kangaroos at sites where the ROO-Guard was on or off. Within treatments, however, site fecal-pellet densities differed ($F_{8,549}=55.675$, $P<0.001$). I found 4 statistically separate groups of sites based on fecal-pellet densities; one treatment site was an influential outlier, with significantly less fecal pellets than at any other site (Dunnet T3, $P<0.001$). When the outlier was excluded from the data set, I found a significant difference in relative fecal-pellet densities at treatment and control sites ($F_{1,7}=13.610$, $P=0.008$); higher densities of fecal pellets occurred at the sites where the ROO-Guard was on.

Fecal-pellet densities did not differ significantly across the 3 sound contours ($F_{2,549}=0.823$, $P=0.440$), and there was no interaction between treatment and contour ($F_{2,549}=1.352$, $P=0.260$; Figure 4). Therefore, kangaroo relative density did not differ with distance from the ROO-Guard.

Discussion

My study does not support the claim made by the manufacturer that both models of the ROO-Guard produce a high-frequency signal that is inaudible to humans; both ROO-Guard models produced audible frequencies. Other sonic deterrence devices advertised as ultrasonic also have been found to produce either a combination of audible and ultrasonic frequencies (Mills et al. 2000) or purely audible frequencies (e.g., Scheifele et al. 1998).

Ultrasonic frequencies are extremely directional (Pye 1979 [cited by Gould 1983]), their noise levels attenuate inversely to the square of the distance in air (e.g., Kinsler et al. 1982), and they attenuate exponentially with increasing frequencies above 8 kHz (Beranek 1971, Manning 1981). Thus, producing and radiating sounds at a sufficient signal level is difficult and expensive. A signal loss of at least 20 dB from 20 to 50 m at the test-condition temperature (18°C) was observed in this study, resulting in

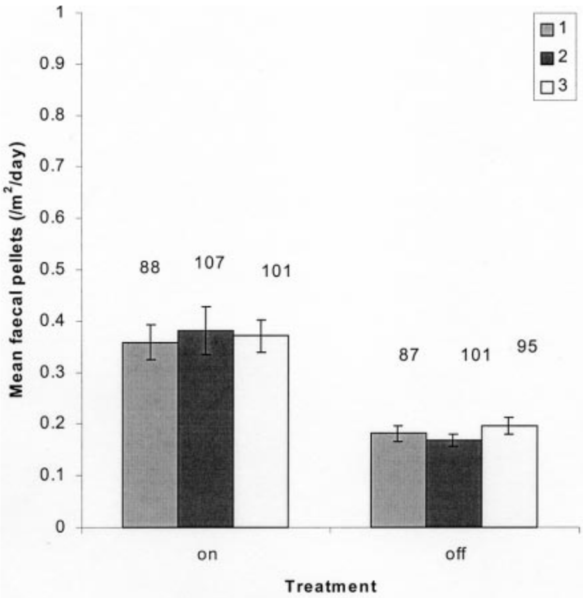

Figure 4. Differences in mean fecal-pellet density between the treatments ($F_{1,\ 8}$ = 0.974, P = 0.353) and across contours ($F_{2,\ 549}$ = 0.823, P = 0.440). Contours 1, 2, and 3 are equivalent to 60, 45, and 30 dB, respectively. Fecal pellets were collected between 12 Dec 1995 and 21 Jan 1996 at open grass sites within Yan Yean water catchment, Victoria, Australia. The numbers of fecal-pellet plots sampled (*n*) are shown.

the signal noise levels dropping from 100 to 70 dB from 2 to 50 m for ROO-Guard Mk I, and 70 to 35 dB from 5 to 50 m for the Mk II. This signal loss was consistent with other studies that have measured attenuation in ultrasonic devices (Woronecki 1988, Bomford 1990, Scheifele et al. 1998). The ROO-Guard did not produce a signal that was loud enough to overcome attenuation at the advertised distance, limiting it to a range of 80–100 m, depending on the model used. In windy conditions, the signal-to-noise ratio is likely to decrease further.

Captive responses

The ROO-Guard MK II had no detectable effect on captive eastern gray kangaroos or red kangaroos at either site, as we observed no significant change in vigilance or flight. This is contrary to the manufacturer's claims, but consistent with other devices tested on other species (e.g., Dryden et al. 1989, Romin and Dalton 1992, Haag-Wackernagel 2000).

Guppy (1985) showed that the gain created by the external ear of the eastern gray kangaroo was greater than 5 dB between 0.7 and 25 kHz, exceeding 15 dB between 1.5 and 12 kHz and having an additional peak at 18 kHz, suggesting that the lower frequencies produced by the ROO-Guard are within the kangaroo's hearing range. The propagation tests indicate that the ROO-Guard was at a distance that should have resulted in an audible signal for the kangaroos. Kangaroos looked toward the ROO-Guard, but this occurred whether the ROO-Guard was on or off, indicating that the sound produced by the ROO-Guard was not attracting their attention.

The ROO-Guard manufacturer claims that kangaroos respond to the ROO-Guard signal because it resembles the sound of their predators when they are hunting. Dingoes (*Canis familiaris dingo*) at night, and wedge-tailed eagles (*Aquila audax*) in the day, are the main nonhuman predators of kangaroos (Robertshaw and Harden 1986). However, spectral analyses of canid vocalizations show that they do not extend above 8 kHz (Fox and Cohen 1977). Raptor vocalizations generally are harsh or harmonic, of wide frequency range, with the greatest acoustic energy between 1.1–6 kHz (Jurisevic 1998). Moreover, predators generally do not vocalize while hunting (e.g., Corbett 1995). Incidental noises made as predators move across the ground (e.g., Henry 1986) may have ultrasonic elements, but are unlikely to concern kangaroos because dingoes do not use stealth while hunting (e.g., Corbett 1995). Kangaroos have been observed to respond to auditory signals given by conspecifics (e.g., Coulson 1997). Vocalizations made by kangaroos tend to be harsh broadband signals below 12 kHz (Guppy 1985, Coulson 1997) and are made during either courtship or agonistic encounters (Kaufmann 1975, Croft 1981), neither of which results in alarm or flight. The only kangaroo signal associated with alarm and flight is not a vocalization but a low-frequency foot thump. A relatively high-frequency signal, such as that produced by the ROO-Guard, is therefore unlikely to convey any social meaning to kangaroos and result in flight.

The distance between the kangaroos and the ROO-Guard may have affected their response. Jarman and Wright (1993) observed an overall mean flight distance (±SE) of 121.4±9.5 m for eastern gray kangaroos when responding to a terrestrial disturbance, either a dingo or a human. All behavioral tests in my study, however, fell within this range, so it is unlikely that kangaroos did not respond because the source of disturbance was outside their flight distance. However, captive kangaroos possibly did not respond to the ROO-Guard because they had been previously exposed to similar frequencies and had become habituated to them. Background recordings at Melbourne Zoo showed the presence of some of the frequencies produced by the ROO-Guard, but I found no such overlap at Werribee Open Range Park at the time that the trials were undertaken. The similarity in response between the 2 captive sites suggests that habituation was unlikely.

Free-ranging responses

Contrary to the manufacturer's claims, similar relative fecal-pellet densities at the Yan Yean treatment and control sites suggest that the ROO-Guard signal did not deter kangaroos. The absence of any significant decline in fecal-pellet densities on sound contours at increasing distance from the source is additional evidence contradicting the manufacturer's claim that the device will deter kangaroos. The background noise levels at Yan Yean Reservoir around the frequencies produced in the ROO-Guard signal (16 kHz filter) were 36–59 dB, but no ultrasonic frequencies were detected using the ANABAT. Consequently, the signal-to-noise ratio should have been good in the frequency range of the ROO-Guard and kangaroos should have been able to hear the signal above any background noise.

Management implications

The promotional literature proclaiming the scientifically proven efficacy of the ROO-Guard grossly exaggerates the capabilities of both models. The results of the signal characteristics, captive behavioral responses, and kangaroo density trials generate 4 clear conclusions: 1) the ROO-Guard Mk I and Mk II do not produce pure ultrasonic frequency signals; 2) the ROO-Guard Mk I and Mk II do not produce signals that are detectable by the testing equipment at 125 m in any direction around the devices; 3) the ROO-Guard Mk I does not alter the behavior of captive eastern gray or red kangaroos; and 4) the ROO-Guard Mk II does not reduce the number of free-ranging eastern gray kangaroos feeding at open grassy sites.

The ROO-Guard is marketed as being effective for kangaroos and wallabies. My study found that eastern gray kangaroos and red kangaroos did not alter their behavior when presented with the ROO-Guard. Statham (1991, 1993) found that the ROO-Guard had the same impact on Bennett's wallabies (*M. rufogriseus*), Tasmanian pademelons (*Thylogale billardierii*), European rabbits (*Oryctolagus cuniculus*), and brushtail possums (*Trichosurus vulpecula*).

The ineffectiveness of the ROO-Guard should caution against the use of other ultrasonic deterrent devices for kangaroos. The results of my study also add to the increasing evidence that ultrasonic devices generally do not provide persistent effects on the behavior of animals (Dryden et al. 1989, Bomford 1992, Coleman and Tyson 1994, Haag-Wackernagel 2000).

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Appendix

Acoustical characterization tests

Measurements of the master ROO-Guard Mk I were made using ANABAT II, a heterodyne bat detector that has a flat response to approximately 50 kHz (R. Coles, South Australian Research and Development Institute, personal communication). A Zero Crossing Analysis Interface Module (ZCAIM) was used to digitally transfer recordings of the master ROO-Guard Mk I to an IBM-compatible 486 laptop using ANABAT II software.

The master ROO-Guard Mk I and Mk II units were mounted on a stand at a height of 1,750 mm above the ground in the center of the grass oval. Noise-level measurements were made using 2 different devices: ANABAT II or a precision integrating sound pressure level (SPL) meter. Measurements were taken to 50 m with the ANABAT II held at chest height (1,280 mm). The ANABAT II was set with a division ratio of 16, and a sensitivity level that ranged from 1.5 to 10. The SPL meter was mounted on a tripod at a height of 900 mm. The SPL meter (B&K 2066) was set to root mean square (RMS), using frontal sound incidence and linear frequency weighting, and the filter was set to 16 kHz. Sound pressure level (dB) measurements were taken from the SPL digital meter (±2 dB) every 2 m along the azimuth bearings using the same method described for the ANABAT II. Results from ANABAT II and the SPL meter were used to create a standard curve so that the ANABAT II sensitivity results could be converted to dB values.