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SHORT COMMUNICATION

Ultrasonic device effectiveness in keeping rodents off the road

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Abstract

Finding achievable ways to reduce roads' impacts on wildlife is a conservation priority. Road verges may be important refuges for small fauna, making them good hunting sites for predators. These make both prey and predators vulnerable to vehicle collisions. Thus, actions aiming to dissuade these animals from approaching roads are needed. Here we tested the effectiveness of ultrasonic devices to keep rodents away from the road verges. We hypothesised that exposing rodents to ultrasounds will cause them to stay away from the device and, consequently, from the road. We sampled rodents before and after the devices were switched on. Our results showed a reduction in animal activity after 10 days with the devices on. The next step is to analyse if this behaviour translates in a reduction of wildlife-vehicle collisions of rodents and their predators.

Keywords Wildlife-vehicle collision · Ultrasounds · Mice · Mortality · Mitigation

Introduction

Roads are a major mortality source for many species (Le Gouar et al. 2011). Reducing the amount of casualties is a conservation priority without a universal solution. Sometimes, particularly when roads cross inhospitable landscapes (e.g. intensive agricultural areas), animals get attracted to road verges using them as refuges, corridors or feeding areas (Ruiz-Capillas et al. 2013). The high prey availability on road verges attracts predators like owls, increasing their road-kill risk (Grilo et al. 2014). Indeed, the abundance of rodents on verges can be higher than in surrounding landscapes (Sabino-Marques and Mira 2011; Ruiz-Capillas et al. 2013). Thus, reducing rodents' activity in the vicinity of roads may prevent vehicle collisions of rodents and their predators (Grilo et al. 2014).

Wildlife-vehicle collisions can be mitigated with the construction of wildlife passages, exclusion fencing or by promoting animal avoidance of roads (e.g. Martinig and McLaren 2019). Measures promoting animal avoidance of roads such as reflectors are employed (D'Angelo and van der Ree 2015), but they are not effective with all taxonomic groups, namely rodents. Another alternative is to use sonic devices for repelling animals (Fox et al. 2018). These devices are commercially available, although their effectiveness in preventing wildlife-vehicle collisions may be little (Valitzski et al. 2009). Animals communicate using specific patterns of frequency, amplitude and duration (Bomford and O'Brien 1990). In particular, rodents reproduce sounds with frequencies between 0 and 110 kHz (which includes ultrasounds: non-audible sounds with frequencies higher than 20 kHz; Sprock et al. 1967), depending on species, age and social situation (Portfors 2007).

Ultrasonic devices have been tested in laboratory and field conditions with inconclusive results about their effectiveness (Bomford and O'Brien 1990; Shumake 1997; Georgiev et al. 2018). Here we tested the effectiveness of ultrasonic devices (hereafter, referred as devices) in dissuading rodents to approach roads. The devices reproduce high-intensity ultrasounds with intermittent output and changing frequencies, which seem to be more aversive than lower-intensity, pure tones (Bomford and O'Brien 1990; Shumake 1997). Due to

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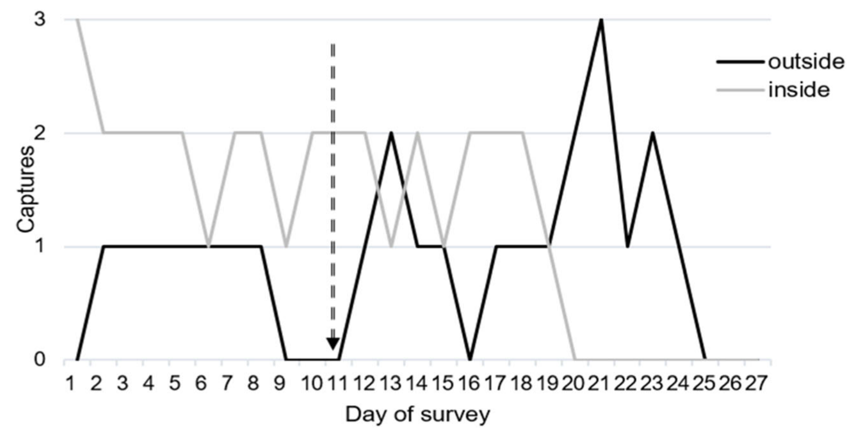

Fig. 1 Number of captures over time: outside (in black) and inside (in light grey) the ultrasound range. The study took place in Évora (Portugal) in July 2018, with a total of 58 rodents' captures. Dashed arrow indicates the day the devices were switched on

the lack of consensus in the literature regarding the practical use of these devices, we decided to test them in natural conditions. We aimed to reduce vehicle collisions of both rodents and their predators'. We addressed as well whether the device effectiveness changes with distance and over time.

Methods

The study was performed in Alentejo (Southern Portugal) from 4 to 30 July 2018, in road stretches with high mortality of rodents and owls (Santos et al. 2011, 2015). The landscape is dominated by Mediterranean agro-pastoral woodlands (known as *montado*) of open oak forests, often grazed by cattle or sheep (Pinto-Correia et al. 2011). We built a device to reproduce continuously high-intensity (120 dB) ultrasounds with changing frequencies (around 32 kHz) and time length to avoid animals' habituation (Supplementary Materials 1). Two devices were installed on the side of a two-lane national road, separated by 120 m, each covering a range of ~ 60 m (30 m to each side).

We followed a before-after study design to evaluate devices effectiveness: rodents were surveyed 10 days with the devices off and 17 days with the devices on. We surveyed longer with devices on to measure possible habituation effects, but could not proceed longer due to extreme weather conditions approaching (Supplementary Materials 2). For each device, we placed 30 Sherman traps along the verge spaced by four metres: 15 inside the ultrasound range (< 30 m) and 15 outside this range (> 30 m). We recorded coordinates for each trap (GPS receptor Trimble GeoExplorer HX, ~ 10 cm error after post-processing). To avoid disturbance effect, the tests only started 2 days after the installation of devices and traps. Each trap was baited with a mixture of oats and sardines and cotton was provided for nesting. Traps were checked daily at mornings for the presence of rodents. Captured animals were identified, sexed and sized. Each animal was marked with small fur cuts and set free at the same place of capture.

We analysed if the number of captures was significantly different with the device off/on and inside/outside the ultrasound range with two goodness of fit G-tests. We evaluated whether time and distance to devices influenced the number of captures with three generalized linear mixed models (GLMM): considering all captures, only captures with devices off, and only captures with devices on. Due to the low number of captures (58), we used a binomial distribution (logit link) with captures as a response variable (0—absence; 1—presence). A location with a presence was defined as any trap with at least one capture for the period being analysed. We used device status (off/on), distance to the device (in meters) and time (day of survey, from 1 to 27) as explanatory variables and

Table 1 Estimated coefficients (β), lower and upper 95% confidence intervals (95% CI), standard error (SE) and significance (p-value) of the three generalized linear mixed models

Explanatory variables	Devices off + on			Devices off			Devices on		
	β (95% CI)	SE	p	β (95% CI)	SE	p	β (95% CI)	SE	p
Intercept	− 1.54 (− 2.50, − 0.65)	0.45	0.0007***	− 1.68 (− 3.67, 2.25)	0.85	0.0475*	− 0.76 (− 2.53, 0.97)	0.88	0.3882
Distance	− 0.01 (− 0.03, 0.02)	0.01	0.6523	− 0.02 (− 0.07, 0.03)	0.02	0.4510	0.00 (− 0.03, 0.03)	0.02	0.9485
Time	− 0.10 (− 0.17, − 0.03)	0.04	0.0062**	− 0.07 (− 0.23, 0.08)	0.08	0.3533	− 0.11 (− 0.19, − 0.03)	0.04	0.0094**
Devices ON	0.87 (− 0.16, 1.90)	0.52	0.0911						
Trap number	Var = 0.35; SD = 0.59			Var = 1.33; SD = 1.15			Var = 0.66; SD = 0.81		

The study took place in Évora (Portugal) in July 2018. *Distance* distance to the device, *Time* day of survey, *Devices ON* device status. Trap number was used as random effect. *Var* variance, *SD* standard deviation. Asterisks denote significance trap number as random effect. Statistical analyses were performed in R v3.4.4. (R Core Team 2018).

Results

The surveys resulted in 58 captures (13 individuals) belonging to two species: *Apodemus sylvaticus* (11 individuals) and *Mus spretus* (2 individuals). Twenty-six were captured with the devices off ($\bar{x}$: 2.6 captures/day) and 32 with the devices on ($\bar{x}$: 1.9 captures/day). The number of captures in each day was consistent (between one and three), except for the last 3 days (no captures). Captures inside the ultrasound range decreased with the devices on (19 with devices off, 15 with devices on) but not significantly ($G = 0.47$; p value = 0.49), while the opposite happened outside the range (7 with devices off, 17 with devices on; Supplementary Materials 2), with a significant increase of captures ($G = 4.30$; p value = 0.04). In the last 7 days (devices on), all nine captures were outside this range (Fig. 1).

Our GLMM dataset with all captures included 563 absences and 58 presences. The number of rodents captured was significantly influenced by time ($\beta = -0.10$; 95% CI = −0.17, −0.03; p value = 0.01) but not by the devices status on and distance to the device. With the devices off, the number of captures was not influenced by distance and time; however, with the devices on, time has a negative influence ($\beta = -0.11$; 95% CI = −0.19, −0.03; p value = 0.01) (Table 1).

Discussion

Our results indicated a reduction of rodent captures after 10 days, likely due to the unfavourable conditions created by the ultrasounds. Rodent captures decreased significantly with time only when the devices were on. After 10 days, captures decreased inside the ultrasound range, and not outside: our data suggest that animals tried to move to outside the ultrasound area. Unfortunately, we were not able to assess for how long this behaviour continued or whether there was habituation, as we stopped fieldwork because extreme weather conditions were approaching. Despite our low sample size and having used only two devices, our results clearly show that rodents tried to avoid the area covered by ultrasounds.

Most commercial devices available promise to get rid of rodents after a few days, varying between 6 and 21 days. Effectively, our devices did not reduce the number of rodents immediately, but only after 10 days. Device users reported positive outcomes, but the majority of studies have found them ineffective or, at most, only temporarily effective (Sprock et al. 1967; Bomford and O'Brien 1990; Shumake 1997; Aflitto and DeGomez 2014; Georgiev et al. 2018). Furthermore, laboratory and field studies often contradict each other (Georgiev et al. 2018). A laboratory study showed that no device was completely effective, even at short ranges ($3.5m^2$), and none were able to deter rodents for more than 3 days (Shumake 1997). However, we did not capture rodents inside the ultrasound area for the last 7 days. In structures with natural presence of rodents at wider ranges (from 16.4 to $196.6m^2$), the authors found again a temporary effect only with one device (Shumake 1997). Several other studies report a small or no effect of ultrasounds with quick habituation (Greaves and Rowe 1969; Maclean 1974; Shumake 1997; Aflitto and DeGomez 2014; Georgiev et al. 2018). Hence, our devices were programmed to randomly change frequencies and time intervals. Habituation is still possible, and thus, we recommend to keep the devices on for a couple of months and switch it off for the same duration.

Sound devices are inexpensive, logistically achievable, and require little maintenance, but have short range and may cause habituation. Moreover, the nature of ultrasound transmission (more directional; do not transmit through objects; rapidly attenuate with distance; Sprock et al. 1967) may influence the practical use of these devices in road ecology. Further research is necessary as well as long-term monitoring to evaluate if the activity reduction is long enough.

To conclude, caution must be taken when deciding where to place the devices. Rodents should not be indiscriminately removed from the verges, as sometimes they are the only remnant habitat available (e.g. for *Microtus cabrerae*; Sabino-Marques and Mira 2011; Ruiz-Capillas et al. 2013). We advise selecting road ditches with suitable habitat in the vicinity (where rodents could move naturally) as well as ditches considered as mortality hotspots for rodents and their predators.

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Compliance with ethical standards

Ethical approval All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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