Effectiveness of acoustic road markings in reducing deer-vehicle collisions: a behavioural study

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The behavioural responses and habituation of fallow deer *Dama dama* to play-back sounds from repeatedly occurring acoustic road markings were studied during 13 nights. Our experimental design eliminated factors normally associated with passing vehicles (e.g. vehicle noise and light), and fallow deer were exposed to play-back sounds from road markings at predetermined time intervals. Though the distribution of the predefined behavioural responses 'flight', 'alarm', 'movement of head' and 'no reaction' varied among nights, the fallow deer exhibited increasing indifference to sounds from road markings with time, and this we explained as being habituation to the acoustic stimulus. As we expect our results to be valid for other species of deer as well, we find that acoustic road markings are not a reliable method to reduce the number of deer-vehicle collisions on a long-term basis.

Key words: acoustic road markings, behaviour, Dama dama, Denmark, fallow deer

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Collisions between deer and vehicles have become very common and pose a safety problem to deer as well as to motorists (Désiré & Recorbet 1985, Kofler & Schulz 1985, Skolving 1985, Prior 1995, Groot Bruinderink & Hazebroek 1996, Putman 1997). Effectiveness of wildlife warning reflectors as a means to reduce

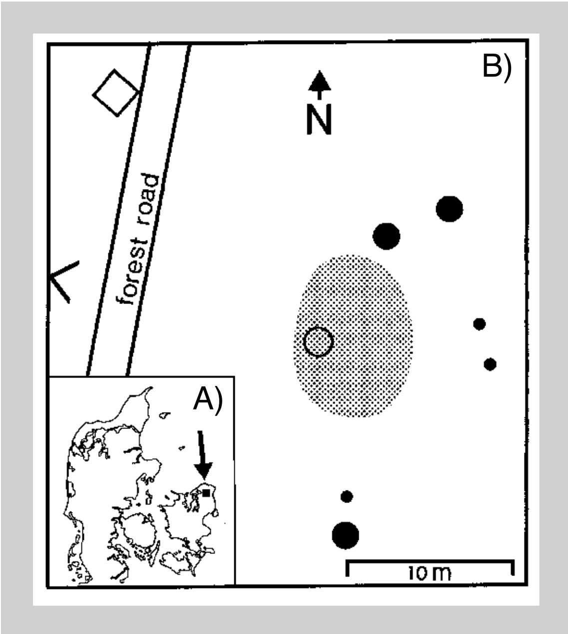

Figure 1. Location of the study site in the forest of Gribskov in northern Zealand, Denmark (A) and the field plot as seen from above (B) with trees (●) and stumps (○) shown. The open square denotes the mobile shed and the angle denotes the location of the shelter for the loudspeaker. The grey area denotes the feeding area.

deer-vehicle collisions has been studied by Ujvári, Baagøe & Madsen (1998) who did not report positive results on a long-term basis. Effectiveness of wildlife warning whistles, considered to influence the behaviour of deer and thereby reducing the risk of collisions with vehicles has been discussed (Schober & Sommer 1984, Muzzi & Bisset 1990, Romin & Dalton 1992). Yet another method to prevent collisions between deer and vehicles is acoustic road markings in which bands of sound producing material are fixed to the road surface in such a way that they emit a strong sound when contacted by the tyres of passing vehicles. The sound produced by these markings is supposed to reduce the number of deer-vehicle collisions by acting as a warning of the deer against the presence of vehicles at longer distances. A precondition for road markings to be effective on a long-term basis is that deer do not cease to respond to the sound stimulus.

In the present experiment, we studied behavioural responses of free-roaming fallow deer *Dama dama* to acoustic road markings in order to test whether or not deer habituate to the sound of road markings over time. To our knowledge, it is the first time that such data are presented.

Study area

The study was conducted in a 5,600 ha forest area of Gribskov (56°00'N, 12°20'E), located in northern Zealand, Denmark (Fig. 1A). The forest vegetation consists of mixed hardwoods, especially of beech *Fagus sylvatica* and oak *Quercus robur*, with interspersed patches of conifers, mainly spruce *Picea* spp. The two most commonly occurring deer species in the forest are roe deer *Capreolus capreolus* and fallow deer, but also sika *Cervus nippon* and red deer *Cervus elaphus* occur (Møller & Staun 1995). Five major roads (two primary [# 6 and # 19] and three secondary [# 227, # 267, # 205]) traverse the Gribskov forest.

A field plot was chosen in the northeastern part of the forest in which the underwood visibility was high due to a vegetation of 150-year old, mature beech and oak stands (Fig. 1B). During winter, a herd of 6-12 fallow deer feed in the area on fodder (maize) spread on the ground. The field plot is undisturbed by vehicles, as the nearest public roads were situated 1.6 km to the north with road # 205 running east-west, and 1.4 km to the west where road # 227 runs north-south. An unpaved forest road, closed for motor vehicles, passed next to the field plot (see Fig. 1B).

Material and methods

Acoustic road markings consisted of material that produces sound when passed by vehicles. The two types of sound producing material that were painted onto the road surface of secondary road # 227 in two consecutive bands of 25 m each were the NCC Roads 'longflex' that emits sounds at low frequencies and the NCC Roads 'spossflex' which produces sounds at a slightly higher frequency. The sound frequencies also varied according to the speed of a passing car. Recordings of the sounds were stored on two compact discs (CD). Each CD contained the sound track of a car passing the road markings, i.e. both longflex and spossflex, which had been multiplied to a total of 70 sequences separated by breaks. The duration of each sequence was < 1/4 second. The sounds on the two CDs differed slightly in their peak frequencies, but both consisted essentially of broad-spectered noises within 0.5-70 kHz. On CD No. 1, the strongest frequencies ranged within 7.0-14.0 kHz and the noise lasted for 0.16 second. On CD No. 2, the strongest frequencies ranged within 5.6-12.0 kHz and the noise lasted 0.11 second.

A mobile shed was placed as a hide for an observer in the field area. In the shed, a Technics SL-XP140 portable CD player (Matsushita Electric Industrial Co., Ltd, Osaka, Japan), a booster (Signat ROC2 Auto Sound Power Amplifier) and a 12 V battery were connected to a home-made loudspeaker placed in a shelter in the forest (see Fig. 1B). The mobile shed and the shelter were set up six and three days, respectively, before data collection was initiated and were then left in the area for the whole study period. From the shelter, the observer exposed the deer to play-back sounds of the acoustic road markings and observed the behaviour of the deer using a Javelin 221 night-vision scope (Javelin Electronics, Torrance, California, USA). The volume matched the loudness of road markings at the secondary road # 227 from a distance of 150 metres, as we did not expect deer to react to vehicles at distances of >150 metres. Hence, the loudness in the deer feeding area was 58 dB. We continued to feed the deer during the study period by spreading maize in the feeding area every day before sunset.

In the period that passed from the sound was turned on until it was switched off, the most powerful response of each deer was recorded on a graduated scale from flight to no reaction, whereby the different levels of alertness and fear can be expressed (Heidemann 1973, Chapman & Chapman 1975, Alvarez, Braza & Norzagaray 1976). We pooled the data from each night and calculated the mean proportion of time that each activity was displayed. We recorded four types of behaviour: 'flight', 'alarm', 'movement of head' and 'no reaction' based on the definition presented by Ujvári et al. (1998).

Data were collected after nightfall during 13 nights between 16 February and 5 March 1997. We used the first two nights as controls during which we did not turn on the sound, but only observed the incidence of the four behaviour types every 15 minutes. Thereafter, we exposed fallow deer to the play-back sound from road markings and collected data on their behavioural responses. Sound exposures and data collection started 10 minutes after arrival of fallow deer in the area, and continued as long as the animals remained in the area. We always used the following six fixed intervals of sound exposure: 5, 2, 7, 3, 1 and 2 minutes, in order to maximise variation in interval differences. During nights 1-10, only CD No. 1 was used. During night 11, CD No. 2 was used exclusively, to study the effect of variations in the acoustics on fallow deer behaviour.

We used χ^2-test twice to test the distribution of the behaviours among nights. We tested: A) the distribution of the behaviours among all nights except during the 11th night (during which CD No. 2 was used) and B) the distribution of the behaviours during nights 1-10. A Spearman rank correlation coefficient test was used

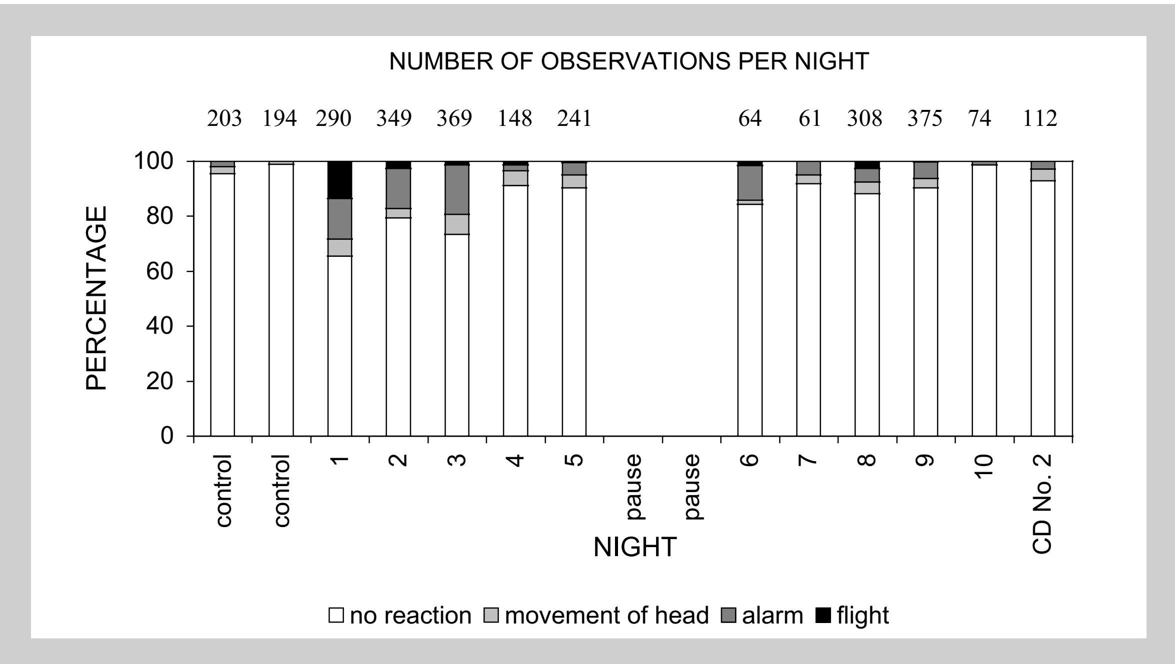

Figure 2. Percentage of occurrence of the four different behavioural types observed for fallow deer in the experiment with acoustic road markings. During the two control nights, the sound was turned off. During nights 1-10, CD No. 1 was used exclusively, and during night 11 CD No. 2 was used. 'Pause' denotes a 1-day break in the experiment, and figures above columns give the total numbers of observations per night.

to test whether a correlation existed between time of sound exposure and the behaviour category of 'no reaction'. We used 'no reaction' in the correlation because we considered acoustic road markings to be ineffective if they do not cause overt behavioural responses in deer. A Spearman rank correlation coefficient test was used on nights 1-10 and nights 1-11, respectively.

Results

The distribution of the four different behavioural responses varied between the two control nights and nights 1-10 ($\chi^2_{33} = 345.21$, $P < 0.0001$; Fig. 2) indicating an initial response to the stimuli. During the two control nights, when unexposed to sound from acoustic road markings, fallow deer never showed 'flight behaviour' and only seldomly 'alarm' (2 and 0%). During the two nights, the predominant behaviour was 'no reaction' (96 and 99%).

When exposed to acoustic stimuli from CD No. 1 (during nights 1-10), the distribution of behaviours varied ($\chi^2_{27} = 250.87$, $P < 0.0001$; see Fig. 2). The first night (night 1), deer either fled from the acoustic stimuli (13%) or were alarmed (15%). However, during the 10 nights of exposure to CD No. 1, the deer reacted increasingly less to the stimuli ($r_s = 0.74$, $P = 0.0202$, $N = 10$). During the last three nights (nights 8-10), the deer showed no reaction at all in 88, 90 and 99% of the cases.

When exposed to CD No. 2 during night 11, the distribution of behavioural responses appeared similar to the responses registered during the last three of the 10 nights that the deer were exposed to CD No. 1 (see Fig. 2). During all nights with acoustic exposures, deer reaction to the stimuli decreased untill the deer stopped reacting at all ($r_s = 0.79$, $P = 0.0036$, $N = 11$).

Discussion

Our experiment demonstrated that the distribution of the four behaviours varied from night to night, and that the percentage of fallow deer that did not react to acoustic stimuli increased with time. This finding corresponds well with the observation that animals repeatedly exposed to a stimulus not associated with any reward or punishment habituate to the stimulus (Manning 1979). Fallow deer apparently did habituate to sounds from acoustic road markings, and 10 nights seem to be sufficient to make deer totally indifferent to acoustic stimuli. This contrasts results of previous studies on fallow deer habituation to light reflections from white WEGU wildlife warning reflectors which showed that 17 nights were not sufficient to make the deer totally indifferent to light reflections (Ujvári et al. 1998).

In our study, only one acoustic sequence was used during the first 10 nights. The frequencies and duration of the sound produced by vehicles passing road markings differ among vehicles due to e.g. differences in speed and tyre air pressure and profile. From our experiment, however, it seems that fallow deer, when exposed to variations in the sound from road markings, still habituate. Our experiment differs from the reality that is perceived by free-living deer in nature, because the sound from the road marking was isolated, i.e. all other stimuli from the passing vehicle were eliminated. However, our set up may quite well simulate the real situation, as sound from the road markings can be heard at a very long distance and some time before the vehicle itself can be heard.

In this experiment, we used fallow deer as a test animal. However, habituation is commonly seen in animals in general (Immelmann 1983) and sound producing devices other than communicative signals have no persistent effect on animals' space use or food intake (Bomford & O'Brien 1990), so we expect our results to be valid for other species of deer as well. We therefore stress the importance of studying the level of habituation to a stimulus when evaluating the efficiency of wildlife warning devices.

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