Development of an Acoustic Deterrent to Prevent Deer-train Collisions

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Deer-train collisions have become a serious problem in Japan. Deer have been observed entering tracks through gaps in fences or at level crossings. To keep deer away from railway lines, an acoustic deterrent was developed and tested for effectiveness. The deterrent consists of a device that emits deer alarm calls and dog calls. Field observations revealed that playing back the deterrent sound towards deer near a track made them run away immediately. According to a survey on the frequency with which deer were observed near railway lines, emission of the deterrent sound from a train resulted in a 45 % reduction in the frequency with which deer were observed for every 100 km of train operation. These results confirmed the effectiveness of the deterrent sound as a measure to prevent deer-train collisions.

Keywords: deer-train collisions, acoustic deterrent

1. Introduction

The number of deer-train collisions has increased rapidly over the last decade despite multiple measures introduced by railway companies: fence construction, and/or spraying repellents along railway tracks; flashing lights to warn train drivers when a deer has entered the tracks; adjusting train timetables and introducing speed restrictions in the light of collision records, etc.

Although the effectiveness of fencing and adjusting driving speeds and timetables to reflect peak collision sections and times, have been confirmed [1], railway companies have been unable to cut the number of collisions significantly because of the steep rise in deer population and rapid expansion of their habitat [2]. New countermeasures are therefore needed, especially those that take into account deer behavior and movement characteristics. Given the scarcity of reports about deer movement around railway lines, observations were made for this study using trail cameras installed around railway tracks.

It is known that there are many deer-vehicle collisions ("roadkill") recorded in Japan. . Studies investigating the use of deer alarm calls have been undertaken to prevent this problem [3]. Results suggest that playing back deer alarm calls from a vehicle can alert deer and prevent them from entering roads. Previous experiments conducted as part of the present research also confirmed that these alarm calls made both domestic and wild deer enter a state of alert [4]. The indication is that deer can become aware of a train approaching at speed when the alarm call is played back from the train. Although alarm calls alert deer, they do not necessarily cause the deer to move from and/or leave the tracks. To prevent collisions however, it is necessary for the deer to clear the railway track immediately after becoming aware of the approaching train. Therefore, in order to achieve this, acoustic stimuli to follow the alarm call were examined. This paper describes this deterrent sound and how it can be used as a new countermeasure.

2. Investigation of deer behavior around the railway track

It is important to know how deer behave around railway tracks to prevent collisions. Their behavior was therefore observed using trail cameras in the vicinity of a railway track, 'Line A' (Fig. 1). It was confirmed that deer entered the railway track through gaps in fencing or at level crossings. According to the report, young deer can pass through a gap 15 cm wide and matured deer can pass through a gap of 17.5 cm wide [5]. Reducing the size of spaces in the fencing would therefore make them more effective. Observations revealed that deer prefer to walk along the fencing to find any openings or gaps when they come across it, rather than jump over it. This indicates that continuity is very important to prevent them from entering the tracks. For the many level crossings on the network, building a continuous barrier however is not realistic, because it would hinder vehicle traffic and pedestrians. Acoustic deterrents could therefore be suitable for such sections because there is no need to change the shape or the surface of the level crossings.

Fig. 1 Deer sightings around the railway track

3. Deer behavior around railway tracks observed from a train

A previous study was already carried out to observe deer behavior from on board a train as it approached the animals [4]. The study was conducted over 8 days and deer were seen 157 times from the cab of the train. Their behavior was classified into two categories: their position as the oncoming train approached and their subsequent behavior. Results showed that 80% of the deer were clear of the train path when spotted. The behavior of these deer was further classified into 8 categories according to their reaction to the train (Fig. 2). Video recordings show that most deer were aware of a train approaching because many of them were facing the train. Then there were three main behavior patterns exhibited toward the train: 1) run away from the track, 2) run along the track, and 3) run across the track. The response of the deer in case of collisions, was: 1) do not move, 2) run along the track, and 3) run across the track immediately in front of the train. Collision prevention therefore depends on the development of a countermeasure that restricts these 3 types of behavior.

Fig. 2 Classification of deer reactions to trains

4. Development of acoustic deterrent consisting of deer alarm calls

It was reported that deer communicate with each other using at least 13 types of vocal sound, including an alarm call emitted in case of danger [6]. It is thought that even if this alarm call is played back repetitively by artificial equipment for collision prevention, given that the sound is instinctively connected to danger, it is unlikely that the deer would become insensitive or unresponsive to it. Furthermore, contrary to many of the other deer cries that are associated with a limited period during the year, such as the mating season, alarm calls are produced year round, which means it is likely to be effective through all seasons.

4.1 Evaluation of the effect of the alarm call

As mentioned before, observation of deer behavior

showed that deer enter tracks via level crossings and through gaps in the fencing. To evaluate the effect of the acoustic deterrent using alarm calls on dissuading deer from entering tracks, an automatic emitter device that would produce the alarm call automatically when a deer was detected near the railway line and a trail camera were installed around the gaps in the fencing as shown in Fig. 3. Deer were recorded twice in the experimental period, and on both occasions, the video confirmed that deer moved onto the track despite the sound of the alarm call. In one case, the deer seemed to hesitate to enter the tracks when hearing the sound. Therefore, although the alarm call did not prevent deer from entering the track, it did appear to make them react and pause in their movement, showing that it could be possible to develop a new countermeasures combining the alarm call and an additional acoustic stimulation.

Fig. 3 Evaluation of the effect of the sound on deer at the gap in the fencing

4.2 Evaluation of the effect of the alarm call

The results above therefore indicated that an additional acoustic stimulation following the alarm call would prevent deer from entering the track. Several options existed, such as using an explosive sound or a siren. However past reports show that deer rapidly get used to these noise if emitted repetitively [7, 8]. It is known that deer fear dogs, and therefore dog calls were added to the deterrent sound after the deer alarm call. In addition, given that the sound would be emitted in real conditions, it was considered necessary to use a natural barking sound. Investigations show that an alarm call is composed of a base tone of 2090 Hz and some multiple tones, whereas a dog bark is composed of a broad range of tones which are completely different (Fig. 4).

Fig. 4 Wavelength spectra of the deer alarm calls and dog barking

5. Evaluation of the acoustic deterrent

To evaluate the effect of the deterrent sound, two types of experiment were conducted (track side and on trains). For both types of experiments, the deterrent sound consisted of deer alarm calls and dog barking. The length of the deer alarm call was 3 seconds in both cases, but the length of the dog barking was different because of the capacity of the device used. In the trackside experiment, dog barking was emitted for 5 seconds, whereas on the trains, it was for 20 seconds.

5.1 Trackside experiment

The acoustic deterrent was recorded in a device which would play the sound when a deer was detected with a motion sensor. The device and trail camera were installed next to the same gap in the fencing that had been used previously for tests using just the deer alarm call experiment. During the experiment, deer approached the gap 6 times, but for unknown reasons, the device only play back the deterrent sound in 3 cases. In two of the remaining cases where the deterrent sound was played deer ran away immediately in response to it (Fig. 5). In the 6th case, a deer strolled near the gap for a few seconds before walking away along the fencing without passing through the gap. These observations, show that the deterrent sound prevented deer from entering the track through the gap, in contrast with the deterrent using only the deer alarm calls. This indicates that combining the deer alarm calls and dog barking together was important to make this preventive measure effective.

Fig. 5 Deer response to the deterrent sound at the gap in the fencing

5.2 On-board experiment

The deterrent sound was designed to be played back from a train, which required installation of an audio system on it. The experiment was conducted along railway line B, where many collisions occurred in winter. Heavy snowfall along the line not only made maintenance of trackside facilities and equipment difficult, it sometimes destroyed the installations. Based on the difficulty of maintaining trackside devices in the line, it seemed more suitable to install an audio system on board a train.

Sound was emitted from trains of the line where frequent collisions had been recorded along the line. Residential areas were excluded to avoid disturbing residents, along with areas running alongside roads, to avoid inducing a deer-road vehicle collisions due to the animals running away from the railway track. Finally, a 55-km-long section was chosen for the test out of the 135-km-long line. For the playback, an audio system was installed in a train and a speaker was settled at both ends of the train. The sound pressure level was adjusted to 90 dB at a point 1 m away from the speaker using a sound level meter (Rion NL-21). The system was operated manually by an observer on the train. To record the deer behavior reacting to the sound, a CCD camera was installed on the train and which was visually monitored by the observer on board the train at the same time. For the control, deer were also observed from trains without any sound being emitted. Collision records showed that most collisions occurred between evening and midnight from November to March. Consequently the experiments were conducted during the following periods: 2016/1/26 ~ 27 (no sound emission), 2/2 ~ 4 (with sound emission), 2/16 ~ 17 (without sound emission), 2/22 ~ 25 (with sound emission). In total, 12 control experiments and 20 experiments with sound, were conducted. During 7 days of train runs with sound being emitted, deer were observed 82 times over the total of 1100 km covered by train runs along the test sections. Cases where more than one deer were observed were still counted as 1, regardless of the actual number of deer. Deer were seen 90 times over a total of 660 km from trains without the sound being emitted over

the 4 days of control experiments. These results confirmed that the frequency in deer sightings (deer sightings/100 km of train operation) fell to 7.4 with the sound emissions from 13.5 without any sound emission (Fig. 6). This shows that the frequency of sightings was reduced by 45 % when the sound was emitted and a chi square statistic reveals that this difference is statistically significant ($p=0.05$).

It is known that weather conditions affect the appearance of deer. However, the weather was relatively stable and there were no drastic climatic changes during the experimental periods. Records show that the frequency of deer sightings in an 80 km no sound section during sound emission operations was 3.8 (sightings /100 km of train operation), and it was 3.9 during without sound emission operation, which demonstrates that there was no significant difference in sighting frequency between sound emission periods and without sound emission. This makes it possible to conclude that the reduction in deer sighting frequency was due the deterrent sound and not to weather conditions.

Fig. 6 Fall in number of deer sightings due to the deterrent sound

5.3 Deer behavior in response to the deterrent sound

The reduction in deer sighting frequency therefore seems to be due to deer leaving the railway tracks on hearing the deterrent sound being emitted from trains. The distance between the train and the deer when they were sighted was estimated using the images recorded from the train (Fig. 7). In cases where the train was playing back the deterrent sound, the distance was found to be 106 m (average of 22 samples). In cases where the train was not playing back the deterrent sound, the distance was found to be 45 m (average of 38 samples). This demonstrates that the distance between the deer and the train was greater when the train was playing back the deterrent sound, than in the control experiments when it was not. These results support the original hypothesis behind this study, and demonstrate the effectiveness of the deterrent sound.

Fig. 7 Distance between the deer and the train

5.4 Discussion

In a paper describing the use of deer alarm calls to prevent deer-vehicle collision in Hokkaido, Japan [9], it was reported that Ezo deer were more frequently alarmed by vehicles emitting deer alarm calls than by vehicles simply passing by. According to this report, Ezo deer reacted to the sound emissions when the vehicle was at a distance of 200 to 300 m. The sound pressure level at this range was estimated to be 39 dB at 200 m to 35 dB at 300 m. This indicated that that Ezo deer were able to pick up these levels of sound.

In the on-board experiment with the acoustic deterrent, the sound pressure level was set to 90 dB at a distance of 1 m from the speaker, which would produce an estimated sound pressure level of around 38 dB at a distance of 400m from the train. This suggests that, according to the report, deer within a distance of 400 m would be able to hear the acoustic deterrent being emitted from a train. In practice, track conditions (curve radius, gradient, presence of vegetation etc.) affect sound transmission so the actual distance would probably be shorter than this.

Reports on the audibility thresholds of Sika deer are scarce, however, there is evidence to suggest that they are capable of hearing sound in the 100 Hz to 50 kHz range [10]. According to experiments Ezo deer are able to detect and are alerted by acoustic stimulation at 2, 7, 10, and 15 kHz [11].

The deterrent sound developed in this report consisted of tones in the 2 to 16 kHz range, which means that it should be audible to and effective on both deer species. Further tests are required however, to investigate the effect of the acoustic deterrent on deer in their different habitats, which may affect their response to the sound.

6. Conclusions

This report describes a new countermeasure to prevent deer-train collisions by means of an acoustic stimulus, “deterrent sound,” consisting of deer alarm calls and dog barking. A device emitting the deterrent sound positioned at a gap in the fencing along a railway line prevented deer from entering the tracks. In addition, the sighting frequency of deer close to the railway line was reduced significantly when the sound was played back from audio systems installed on trains.

Previous reports have confirmed the effectiveness of fencing and adjusting train timetables in accordance with collision data to avoid peak collisions times. However, new countermeasures became necessary following the ongoing rise in number of deer-train collisions in Japan. The acoustic deterrent can therefore serve as a reliable countermeasure to this problem. Further experiments are necessary however, to determine its long-term effectiveness before the deterrent is applied in practice and brought into service on the railway network.

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