Chapter 17
Wildlife Deterrent Methods for Railways—An Experimental Study

Andreas Seiler and Mattias Olsson

Abstract Since reliable accident statistics and consequent costs have become available, train collisions with wildlife, especially ungulates, have received increasing attention in Sweden. In contrast to collisions on roads, accidents involving wildlife on railways do not entail human injury or death, but can cause substantial train damage and lead to significant delays in railway traffic. Wildlife-train collisions (WTC) are rising in numbers and railways appear as a greater source of ungulate mortality per kilometer than roads. Nevertheless, railways are largely unprotected against wildlife collisions, and mitigation measures that have hitherto been applied to roads are either infeasible or economically unviable for railways. The Swedish Transport Administration is therefore seeking innovative and cost-effective measures for preventing collisions with larger wild animals. In this chapter, we present research on WTC in Sweden that has been used to define the baseline and set up criteria for a new mitigation project. This project aims to develop warning or deterring signals that encourage animals to leave the railway shortly before trains arrive. This will be carried out at several experimental crosswalks for animals along fenced railways where the effect of different signals on animal behaviour can be evaluated. If effective, these deterrent systems could replace fencing and/or crossing structures, and reduce mortality and barrier effects on wildlife. The project was begun in 2015 and will continue for at least 4 years.

Keywords Accident prevention · Animal-deterrent · Crosswalk · Deer-train accidents · Exclusion fences · Hotspots · Wildlife-train collisions · Wildlife-warning

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Introduction

Wildlife-train collisions (WTC) on Swedish railways have steadily increased over the past 15 years (Fig. 17.1), totalling about 5,000 reported incidents with moose (*Alces alces*), roe deer (*Capreolus capreolus*), reindeer (*Rangifer tarandus*), and other ungulates (fallow deer, red deer, wild boar) every year (Seiler et al. 2011; Olsson and Seiler 2015). The number of unreported WTCs, as well as the number of collisions with smaller mammals and birds, is unknown. WTCs receive increasing public media attention and their importance is also acknowledged by train operators and the Swedish Transport Administration (Olsson and Seiler 2015). WTC can cause significant disruptions and delays to train traffic; produce considerable repair costs for material damages; and entail further costs related to the retrieval and handling of animal carcasses, the loss of other economic values of

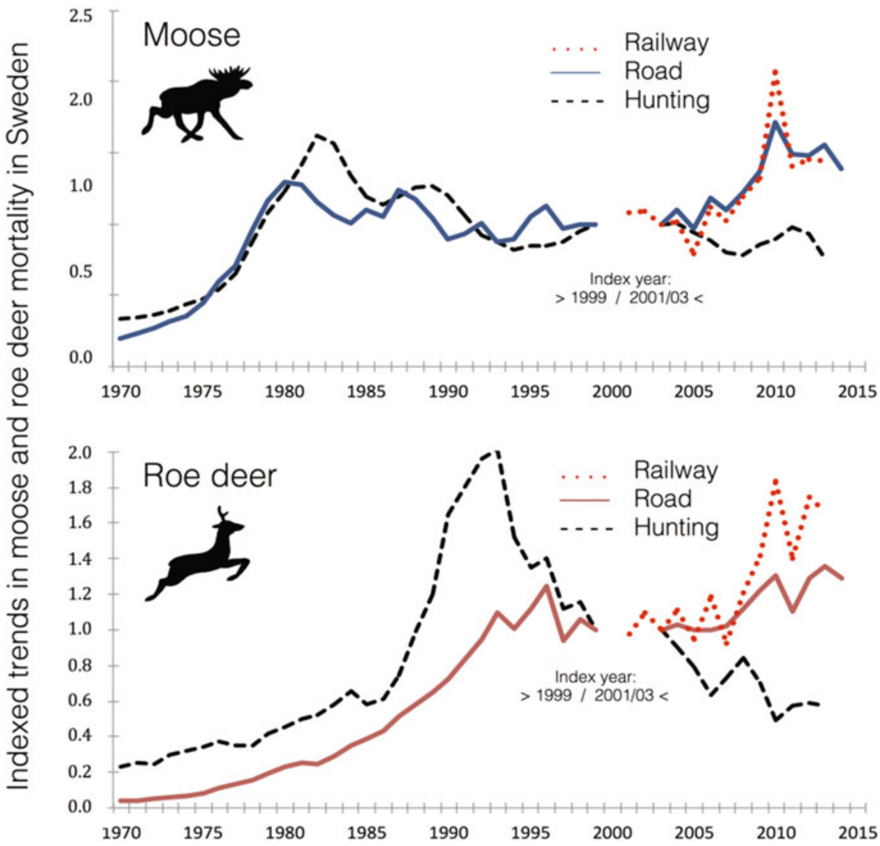

Fig. 17.1 Trends in moose and roe deer reportedly killed on roads, on railways and through hunting. Traffic accounts for about 10–15% of all human-caused mortality, and the proportion is increasing. (updated from Seiler et al. 2011)

wildlife, and the administration of accidents (Child and Stuart 1987; Jaren et al. 1991; Gundersen and Andreassen 1998).

However, since WTCs do not cause human injury or death, and hence are not considered a traffic safety problem, the Swedish railway network is still largely unprotected against collisions with wildlife. Except for a few railway sections in the northern region, where accidents with semi-domestic reindeer lead to expensive reimbursements, fencing has long been regarded as economically unviable for railways, and alternative measures have not been seriously tested. This attitude, however, is changing as train operators upgrade their train systems to modern light-weight multiple-unit trains. These trains are less robust than traditional single train engines and require more expensive repairs after a WTC, sometimes leading to significant delays in railway traffic. The overall socio-economic costs of WTCs in Sweden have recently been estimated at 100,000,000–150,000,000 million Euros per year (Seiler et al. 2014). This is similar to the costs estimated for wildlife-vehicle collisions on roads (250,000,000 Euros per year) (Seiler and Olsson 2015), despite railways comprising less than 2% of the national road network. Thus, the number of collisions with larger wildlife, especially ungulates, per kilometer, is greater on railways than public roads.

Preliminary analyses of the Swedish railway network suggest that there are at least 10 railway sections with very high WTC frequencies where fencing would be economically viable today. On most railway sections, however, fencing still may not be cost-effective. Alternative methods, such as wildlife deterrents or warning systems, need to be developed to keep animals off railways, at least when trains approach. Initial attempts with such wildlife warning systems in other studies have produced promising results (Larsson-Kråik 2005; Werka and Wasilewski 2009; Babińska-Werka et al. 2015; Shimura et al. 2015).

Therefore, the Swedish Transport Administration, in cooperation with Swedish Railways, Enviroplanning AB, and the Swedish University of Agricultural Sciences, initiated a project in 2015 to develop and test methods for deterring wildlife from railways when trains approach. In this chapter, we describe the research that provided the baseline for this unique project and describe its specific settings and objectives.

Background

Wildlife-train collisions (WTC) on Swedish railways were not scientifically studied before 2011 (Seiler et al. 2011) because empirical data was not accessible, and authorities did not perceive WTC as a problem and thus did not finance research. Collisions with semi-domestic reindeer were an exception, probably because rail authorities had to reimburse reindeer owners and therefore maintain detailed statistics (Åhrén and Larsson 1999, 2001). WTCs are reported by train drivers via telephone to a central register. Based on these reports, railway patrols and specially trained hunters visit the accident site to remove the carcasses or take care of the wounded animals. We compiled these reports and analyzed spatial and temporal patterns in the distribution of WTCs. We also surveyed train drivers regarding their experiences with wildlife on railways and wildlife-train collisions. These studies provided the framework for the preparation of the current mitigation project, whose main findings are summarized below. The major objectives were to evaluate the magnitude of the problem, obtain input on potential mitigation measures, analyze spatial and temporal patterns, and identify the hotspots where mitigation might be most urgently required.

Train Driver Survey

In 2010, we conducted a survey with train drivers to map their experiences with WTCs (Seiler et al. 2011). Drivers were asked about how often they observed animals on or near the railway, how often they experienced collisions with ungulates, and how animals typically responded to the oncoming train. Train drivers were also asked for their opinions and ideas on how to reduce WTCs. About 17% of the 1,023 participants took an active part in the survey, and over 65% of the respondents replied that they encountered deer several times a week. Most respondents (91%) had experienced collisions with roe deer (49.3%), moose (23.5%), reindeer (19.4%), and other larger wildlife (7.8%) during the previous year. This matches the overall accident statistics, in which these three species make up over 90% of all reported cases (Fig. 17.2). Collisions with wild boars (*Sus scrofa*), fallow deer (*Dama dama*) or red deer (*Cervus elaphus*) are rare, probably because these species are more restricted in their geographic distributions.

Train drivers perceived poor visibility, thick vegetation, poor light conditions, and deep snow as the main causes for WTCs. These factors may cause the animals to detect approaching trains very late or be unable to escape in time. However, train

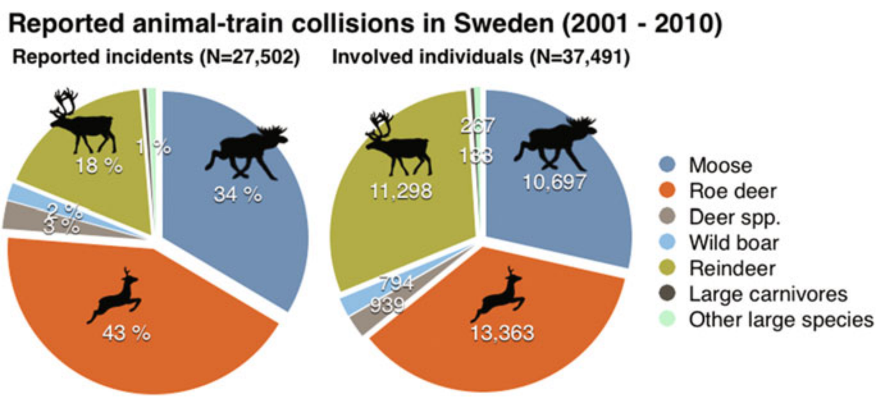

Fig. 17.2 Reported wildlife-train collisions in Sweden during 2001–2010 *Source* Seiler et al. 2011)

drivers also reported that many animals in the vicinity of the railway rarely seemed to react to passing trains. Flight behaviour was not often observed, but if flight was initiated by the train or by warning signals (horn), the animals sometimes fled ahead of the train and along the rail (see also Rea et al. 2010; Child 1983). Animals sometimes even walked up on to the railway track as the train approached, presumably to gain speed during flight (Child 1983).

Most train drivers (90%) were concerned about damage to the train, traffic delays, and unnecessary suffering and non-fatal injuries to the animals. Many drivers considered WTC to be a severe working environment issue because of the psychological stress they cause. Since train drivers are not able to slow down or stop the train to avoid a collision, their only options are to use the horn or flash the headlights in order to alert animals. However, most drivers disagreed about whether these measures are effective.

Collision Statistics

About 2,500–3,000 collision reports were issued every year from 2001–2010, including, on average, 1,070 moose, 1,336 roe deer and 994 other large mammals killed or injured annually (since accidents may involve more than one individual; Fig. 17.1). The number of unreported cases and undetected incidents is not known, but is assumed to be large and more pronounced in the smaller and lighter species. Since 2001, accident reports on roe deer and moose have increased by about 2.5% per year, despite decreasing hunting statistics that suggest smaller populations. The trend in WTC reflects trends in wildlife-accident numbers on roads (Seiler 2011). This follows both a similar diurnal pattern to road accidents with most collisions occurring during dusk and dawn, and a similar seasonal pattern with most accidents reported during autumn and winter (Neumann et al. 2012; Borda-de-Água et al. 2014; Rolandsen 2015). Likewise, as on roads (Seiler and Helldin 2006; Jacobson et al. 2016), WTCs were more frequent on railways with intermediate traffic volumes (50–150 trains per day) and less frequent on both calmer and busier tracks.

Overall, wildlife collisions on railways and roads seem to share many characteristics and patterns. However, collisions with moose appeared to be twice as frequent per kilometer of railway (and with roe deer slightly more frequent) than on public roads, suggesting that railways may be more dangerous than roads on average. We assume that this may be related to the relatively long intervals between trains; animals may be deterred less often by railway traffic and use railway tracks more readily than roads, because trains pass by less often.

In Sweden, WTCs are reported by train drivers not as an actual GPS position, but as incidents occurring between two consecutive nodes in the railway network. Thus, WTCs contain no point statistics, but rather frequencies related to a given section of railway. These sections average 8 km, but range from a few hundred meters to 53 km. A total of 1,377 sections longer than 1 km were included in the study. On average, during 2001–2011, annual reports yielded 0.79 moose and 1.09

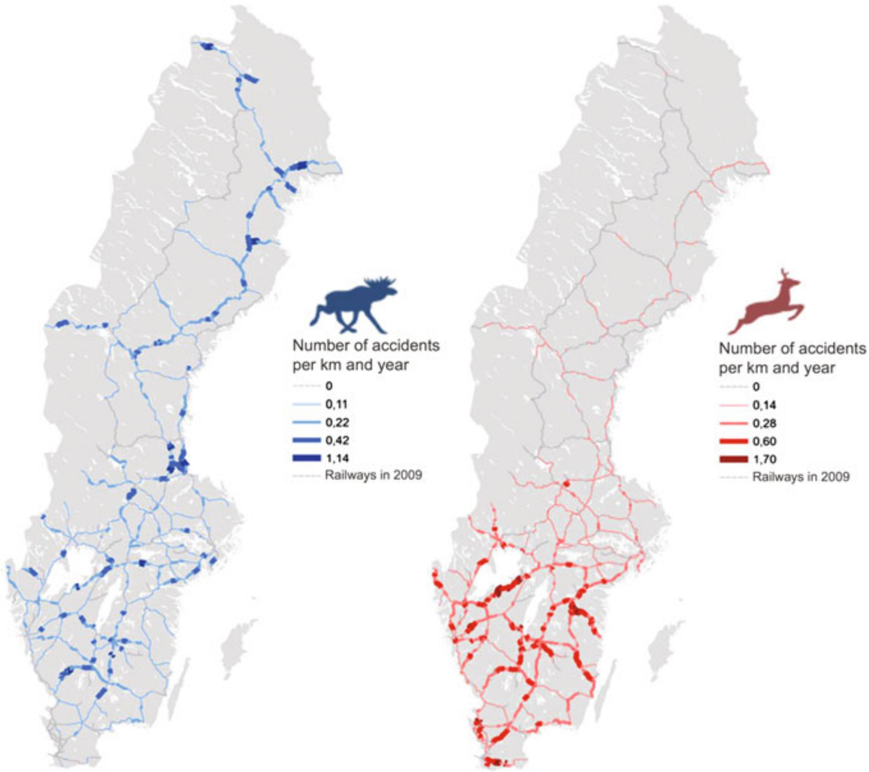

Fig. 17.3 Annual frequencies of reported and positioned train collisions with moose and roe deer per km of railway in Sweden during 2001–2009. (from Seiler et al. 2011)

roe deer incidents per 10 km railway per year. On some sections, however, densities would exceed one accident per km per year (Fig. 17.3).

WTC Hotspots

We identified special aggregations of WTCs or "hotspots" as railway sections with collision frequencies above 2.38 collisions with moose and 3.30 collisions with roe deer per 10 km per year, which corresponded to the top 5% at the national level. We then ranked hotspots according to their stability over time, with high-ranked sections comprising those that were among the top 50 sections in more than four of seven overlapping 5-year intervals during 2001–2011. For comparison, we selected "coldspots" as sections for which no WTC had been reported during the study period. Logistic regression analyses successfully distinguished between "hotspots" and "coldspots" based on the composition of the surrounding landscape, availability of suitable forage, and preferred habitat, and the presence of linear structures, such as minor roads and water courses that would lead animals toward the railway or encourage them to cross (Seiler et al. 2011).

From the top 50 hotspots, we then selected those that contained more than one ungulate species besides moose, had high traffic volumes and were used by SJ passenger trains, and had been subject to vegetation clearance (tree felling) within a 30-m wide corridor alongside the railway. In addition, the railway sections had to run primarily through forest-dominated landscapes and not through built-up areas. With these criteria, we eventually selected three railway sections for the experimental mitigation study (Olsson and Seiler 2015) (see below).

Wildlife-Train Encounters

In cooperation with Swedish Railways, we initiated a new project in 2015 to study the behaviour of animals when they encountered an approaching train. This was carried out using video recordings made by train drivers on a commercial dashcam (DOD-LW730). The dashcam records continuous video in 1–5 min clips, but overrides old recordings when memory capacity is full. If the camera alarm is set off, however, a recording in progress is protected and can be extracted for later analysis (Fig. 17.4). The advantage of this approach is that the alarm does not need to be set immediately, but can be made after the incident in question occurred. In this project, 15 train drivers volunteered to use a dashcam during their daily work routines. They were instructed to set off an alarm whenever they saw an animal on or near the railway. While this project is still ongoing (as of October 2016), preliminary findings from the first 178 recordings confirm the previous driver survey results: many ungulates utilize rail corridors for browsing or transport (see also Jaren et al. 1991). Most individuals were attentive to traffic, but in about 15% of the documented encounters, animals did not respond to the approaching train. The overall kill rate was 5% in both moose and roe deer. Mean flight initiation distances were short in both species (112 and 125 m, respectively), leaving the animals less than 2 s to respond correctly and leave the track when a modern passenger train approached at about 200 km/h. Flight initiation distances varied slightly, depending on whether the animals were on the track or beside the track, but due to the limited number of observations, these differences are not yet significant. They suggest, however, that animals may less easily detect approaching trains when on the railway tracks or be unable to distinguish risks, depending on how close they are to the railway. We could not detect any effect of the horn or the headlights used by the driver to warn animals, but as the study continues, we hope to find out whether acoustic or optic signals help to increase flight distances and reduce the risk for collisions.

Fig. 17.4 Train driver's view of a fleeing moose shortly before collision (above). The picture was taken with a video dashcam mounted inside the driver's cabin. The damaged front of the X2000 train engine after the moose collision (below) (*photos* Jimmy Nilsson, Swedish Railways)

Ultimate and Proximate Causes of WTCs

Based on these previous studies, we can identify various factors that influence collision risk.

Clearly, WTCs are more frequent in areas with higher wildlife abundances (see also Gundersen and Andreassen 1998; Hedlund et al. 2004; Seiler 2005), or where animals are more likely to cross railways. This relates to landscape composition, food availability, landscape structure, and other regional and local factors typically beyond the responsibility of the train operator or the railway manager (Seiler et al. 2011; Rolandsen 2015). Other factors relate to the attractiveness and accessibility of the railway, including vegetation management alongside railways (Jaren et al. 1991; Rolandsen 2015), the presence of gullies and fences, or by train density (Righetti and Malli 2004; Kusta et al. 2011).

The proximate cause of WTCs, however, must be attributed to the behaviour of the animal itself. In contrast to roads, where motorists carry the main responsibility for avoiding collisions with wildlife (Seiler and Helldin 2006; Litvaitis and Tash 2008), trains are unable to stop or change paths. Therefore, it is only the animal that can avert a collision, but this depends on its chance of detecting an oncoming train in time, its cognitive abilities, and its anti-predator or flight behaviour. As we have seen on video recordings, flight initiation distances were short, leaving little time for the animals to respond appropriately, especially to rapidly moving and silent modern passenger trains (Gundersen and Andreassen 1998; Rea et al. 2010). Therefore, a possible mitigation is to increase the available response time by alerting animals earlier, before the train is too close to be avoided.

Mitigation Project

Objectives

In 2015, the Swedish Transport Administration, in cooperation with Swedish Railways, Enviroplanning AB, and the Swedish University of Agricultural Sciences, initiated a project to develop novel approaches and test available systems for alerting and deterring wildlife from railways shortly before trains arrive (Olsson and Seiler 2015). The goal is to prevent WTCs while still allowing animals to cross the railway when no trains are approaching.

Earlier studies from Poland (Werka and Wasilewski 2009; Babińska-Werka et al. 2015) have been promising, but further technical and methodological development is needed to develop a cost-effective and robust alternative to fences and crossing structures.

Approach

To develop and test wildlife warning systems, we selected three railway sections (8, 11 and 23 km in length) with extreme WTC frequencies ("hotspots") and two other sections for practical reasons. All five sections will be fenced, using 2 m high standard exclusion fences of a type also used along roads. These fences will be perforated by 20–24 experimental crosswalks, i.e., gaps in the fence of about 50 m that are monitored by video and thermal cameras and secured by the alerting or deterring systems (Fig. 17.5). The fences thus serve two purposes: they reduce WTC on most of the railway section by an estimated 80% in moose and 60% in roe deer (Swedish-Transport-Administration 2014), and they lead animals toward the openings at the crosswalks.

These experimental crosswalks serve as test locations where the effect of various stimuli can be studied (Fig. 17.5). They thus provide independent replicates and controls in a BACI setup (BACI = Before, After, Control, Impact). The crosswalks will be placed at feasible locations where animals are known to cross the railway (detected by snow tracking) and are dispersed approximately 2 km apart, providing an estimated sufficient level of permeability to moose and roe deer (Seiler et al. 2015). The crosswalks will be constructed so that terrain conditions, vegetation and ground substrate naturally and effectively lead animals toward the fence gap and

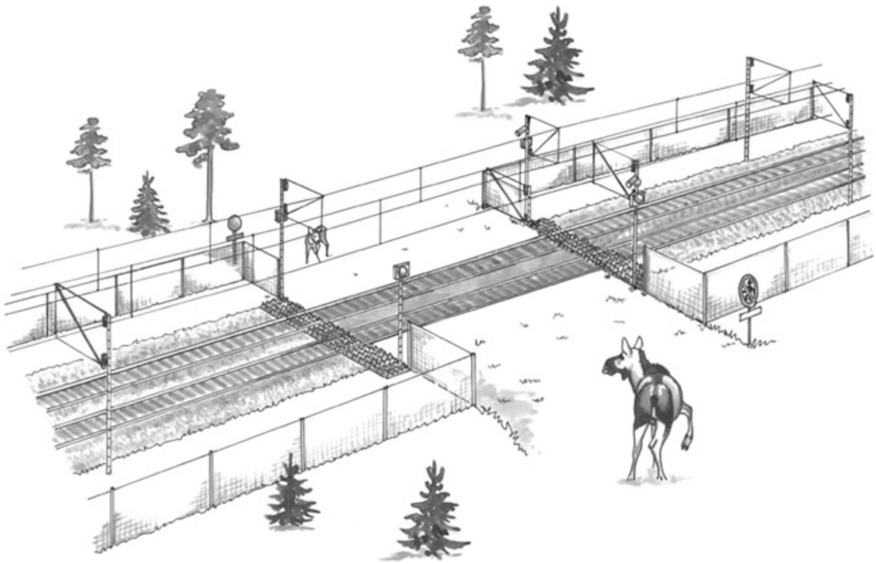

Fig. 17.5 Conceptual sketch of an experimental crosswalk: standard exclusion fences lead animals towards an opening about 50 m wide where movement detectors, thermal cameras, and video cameras monitor the presence and behaviour of animals and trigger the warning system when trains approach. Crushed stone or cattle guards will discourage ungulates from entering the fenced area. Human access to the crosswalk is prohibited (*sketch* Lars Jäderberg)

over the railway. Cattle guards or large crushed stones alongside the crossings will discourage animals from entering the fenced railroad track. Escape ramps or one-way gates will be installed to allow animals to exit if they get trapped inside the fence nevertheless.

Providing the same animal detection and monitoring and surveillance systems, each experimental crosswalk will operate as an independent unit that will be triggered by the same signal from a standard train sensor located several kilometers earlier along the railway. One train sensor will serve several crosswalks, and the delay between the train passing the sensor and the alarm at each crosswalk will be adjusted to the speed of the train and the distance between the crosswalk and the sensor. Warnings will only be displayed when animals are detected near the crosswalk and a train has passed the sensor, i.e., when the risk of a collision is imminent. This basic setup will be identical at all crosswalks and guarantee a standardized basis for the evaluation and comparison of different warning methods.

We budgeted 150,000–270,000 Euros per experimental crosswalk that includes surveillance equipment and warning systems. If such systems were installed on a regular basis, the costs would be substantially lower. The overall budget for the 20–24 crosswalks along 50 km of fenced railways was 5.5 million Euros in total (minimum cost estimate 4,500,000 million Euros and maximum estimate 7,800,000 million Euros) (Olsson and Seiler 2015). Most of the budget is reserved for fences (about 50,000 Euros per km), while research money totalled about 5,500,000 Euros over 4 years. However, if one assumes that over the next 20 years, WTC levels and the average costs for repairs, delays, and reimbursements are similar to those of the last 10 years, and at least 80% of the WTCS could be prevented by fences and/or crosswalks, then the socio-economic costs that could be saved by mitigating the selected hotspots alone would exceed 4,600,000 Euros. However, it is likely that the overall costs for the installation of the experimental study will be outbalanced by the savings, because the benefits are easily underestimated (Olsson and Seiler 2015; Seiler et al. 2016).

The Deterrent System

Traditional attempts to scare animals away from fields, roads, and airports by means of ultrasonic whistles, explosionss or shooting guns have mostly been ineffective (Koehler et al. 1990; Romin and Dalton 1992; Curtis et al. 1997; Belant et al. 1998; Ujvari et al. 2004). The underlying problem is that when the warning signal is not followed by a real threat and is merely a bluff without consequence, animals will soon habituate and learn to ignore the signal (Bomford and O'Brien 1990). In our approach, we rely on the passing train to reinforce the signal. In most cases, as we have seen in our video recordings, the train will be frightening enough when it is nearby. Habituation should therefore not be a problem; instead, learning should instead lead to a conditioning, provided the animals are able to relate the signal to the approaching train. Conditioning will presumably work best in those individuals who have an experimental crosswalk within their home range and thus repeatedly experience the signal and the passing train. However, there will always be a proportion of animals (offspring, dispersers, and migratory animals) that are not yet conditioned or do not know about the danger of traffic. Thus, rather than using abstract stimuli, such as whistles or bangs that would alert humans, it may be more effective to use natural sounds that already communicate a message for animals, such as a human voice indicating the presence of people, or a deer warning or distress call for alarming other animals.

Such approaches have been tested in Poland using animal alarm calls, barking dogs and sounds from hunting scenes (Werka and Wasilewski 2009; Babińska-Werka et al. 2015); in Japan, using sika deer warning calls (Shimura et al. 2015); in Italy, using sounds of dogs and humans to scare wildlife off roads when cars approach (Mertens et al. 2014); and in Northern Sweden, using human voices from a conventional radio to alert semi-domestic reindeer (Larsson-Kråik 2005). Experiences from these studies suggest that such warning systems may be effective in causing the animals to leave the disturbed site.

The basic idea is thus to condition a movement response to an auditory and/or visual stimulus that is strong enough to evoke the desired, subtle response in most individuals, but weak enough to avoid causing a panic reaction and allowing the animals to experience reinforcement through the passing train.

We intend to address questions such as which signals will work best, how quickly animals learn to respond appropriately, and to what extent this reduces the risk of collisions. If the systems prove successful in moving wildlife away from the railway track when trains approach, they could replace more costly crossing structures such as bridges or tunnels and provide the necessary complement to fences in an inclusive mitigation system (Huijser et al. 2009; Seiler et al. 2016). If the system is to replace fencing, however, the deterrent or warning effect must be extendable over several kilometers. This may be evaluated in a later study. If the system does not operate successfully, i.e., if animals show very little response to warning signals, and if collisions in the crosswalks are not reduced, the gaps in the fences may need to be closed.

Complementary Studies

Besides the aforementioned system of crosswalks and fences, the project will involve complementary activities such as in-depth analyses of WTC statistics; field surveys to assess unreported collisions; improvements to the reporting and registration routines of WTCs; studies on the indirect costs of WTCs due to delays in train traffic; exploration of possible animal detection and warning systems that can be mounted on train engines instead of in railway infrastructure; and continued video monitoring of train-animal encounters. Collaborations with similar research projects in Norway and Austria have been initiated. An international reference group will be established together with a group of private companies interested in testing their technical solutions and ideas for a warning system.

Parallel to this project, empirical studies are being conducted to reduce wildlife-vehicle collisions on roads; in combination, these studies will help to develop national objectives and set up a national strategy for reducing wildlife and traffic problems in Sweden.

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