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A test of wildlife warning reflectors as a way to reduce risk of wildlife-train collisions

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Abstract

Looking for an effective method to reduce risk of animal-train collisions, we tested the system of wildlife warning reflectors, a method usually used on roads. The research was conducted in central Poland, along a 2.1 km stretch of the E65 railway line near Warsaw, during eight months, in the years 2010–2011. For six months of a test period, the reflectors were uncovered (active) and, for the next two months of the control period, they were covered (non-active). Digital cameras were used to register animal reactions to trains 24-hours per day. We compared the probability of escape (escape = 1; no reaction = 0) from an oncoming train during test and control periods of the research, in different parts of a day (i.e. day vs. night) and compared escape time of roe deer between day and night and with reflectors covered and uncovered. Roe deer (*Capreolus capreolus*), red fox (*Vulpes vulpes*) and brown hare (*Lepus europaeus*) were observed most often (702 observations in total). The status of reflectors (covered/uncovered) did not influence the probability of animals' escape from an oncoming train. The only factors that affected the probability of escape were animal species and time of a day. Of the three species, roe deer was most likely to escape from an oncoming train (89% of probability at day and 52% during night, pooled data for covered and uncovered reflectors). Timing of roe deer escape from an oncoming train did not differ between day (6.4 seconds) and night, with either reflectors covered (7.5 seconds) or uncovered (4.6 seconds). The results indicated that wildlife warning reflectors were not effective to modify animal behaviour and to reduce risk of animal-train collisions.

Keywords

Animal-train collisions, mitigation measures, railway lines, roe deer, wildlife warning reflectors

Introduction

Transportation infrastructure, namely roads and railways, is one of the most widespread threats to wildlife. Transportation infrastructure fragments habitats by cutting through the individual territories and migration corridors of wildlife (Cain et al. 2003; Di Giulio et al. 2009; Ito et al. 2013; Borda-de-Água et al. 2017). As transportation networks continue to expand, the frequency of collisions between wildlife and vehicles increases (Jasińska et al. 2019). Loss of individuals to wildlife-train collisions can have large impacts on mammal populations, particularly for species that are endangered, have low population densities, have large home ranges and low reproductive rate (van der Grift 1999). For example, in a vulnerable population of grizzly bears (*Ursus arctos*) in Canada, train strikes have become a major cause of mortality (St. Clair et al. 2019). The number of wildlife-train collisions is much lower than wildlife-vehicle collisions recorded on roads (Cserkész and Farkas 2015) and research on collisions between trains and wildlife have so far focussed mainly on medium or large mammals (Kušta et al. 2011; review in: Steiner et al. 2014; Krauze-Gryz et al. 2017; Pollock et al. 2019), with moose *Alces alces* being the focal species in most papers (Andersen et al. 1991; Child et al. 1991; Jaren et al. 1991; Modafferi 1991; Gundersen et al. 1998; Hamr et al. 2019). Although risk of human injuries is usually low in train collisions, they cause significant delays to train traffic, considerable costs regarding material damage and other costs related to handling of animal carcasses or injured animals and administration of accidents (Child and Stuart 1987; Seiler and Olsson 2017).

To reduce wildlife-vehicle collisions, many methods can be used. On roads, over forty mitigating measures have been described, influencing either the driver behaviour (e.g. warning signs, animal detection systems) or animal behaviour (mostly by deterring animals from roads) (review in: Glista et al. 2009; Langbein et al. 2011; Rytwinski et al. 2016). Railway transportation is different from road transportation; for example, train traffic volume is lower, with long traffic-free intervals (Barrientos et al. 2019), thus mitigation methods used on railways should be different from those used on roads. Although fencing is considered to be the most effective measure to restrict wildlife access to railways (Ito et al. 2013), it causes serious fragmentation, so measures to maintain ecological connectivity are necessary (Carvalho et al. 2017). Moreover, because railways themselves are considered as a barrier for wildlife movement (Ito et al. 2013; Ito et al. 2017), the use of additional barriers along railway tracks should be discouraged (Carvalho et al. 2017). Thus, the mitigation measures used on the railway should focus on changing animal behaviour and forcing animals to escape when the train approaches rather than preventing animals from crossing the tracks at all (e.g. Babińska-Werka et al. 2015; Seiler and Olsson 2017).

One of the methods designed for roads and to mitigate wildlife mortality is the use of wildlife warning reflectors and mirrors (Rytwinski et al. 2016). This mitigation method has been developed to increase wildlife vigilance and awareness of oncoming vehicles (D'Angelo et al. 2006). Reflectors are mounted along the road on series of roadside posts orientated towards the road verge. At night, vehicle headlights illuminate the warning reflectors, which reflect light towards the road verge to create a “fence of light”. The intent is that an animal will notice the reflected light and halt or flee away from the road until the vehicle had passed and then cross safely (D’Angelo et al. 2006; Benten et al. 2018a). Findings of different studies on the effectiveness of wildlife reflectors along roads are contradictory (Brieger et al. 2016; Benten et al. 2018a). Some of them pointed to the effectiveness of wildlife warning reflectors in reducing the number of wildlife-vehicle collisions (e.g. Schafer et al. 1985), while another showed no such evidence (e.g. D’Angelo et al. 2006). On the other hand, nothing is known about the effectiveness of relectors implemented along rail tracks.

The aim of the study was to determine the effectiveness of wildlife warning reflectors installed along the railway tracks, i.e. the likelihood of animals' escape from an oncoming train. We compared the reaction of animals to oncoming trains during nights and days, assuming that, at night, animal behaviour should be modified by the reflectors, while at day, their influence should be negligible (Benten et al. 2018a). We also compared reactions of animals to oncoming trains at night, with reflectors active (uncovered) and non-active (covered), assuming that, in the second case, animals would escape from an oncoming train less often and slower.

Methods

Study area and installation of reflectors

The research was conducted in central Poland, along the stretch of E65 railway line, between Warszawa Choszczówka and Legionowo (52°39'N, 20°96'E). This section of tracks is surrounded by a small forest complex (around 1300 ha) (Fig. 1), located in the vicinity of field and forest mosaic as well as urban area. On a given stretch of railway, three tracks were located. Trains run almost all day with a break between 0:00–4:00 a.m. On average, 90 trains run daily through the study area with 100–120 km/h speed (Polskie Koleje Państwowe 2014). The study area was characterised by the presence of ungulates – moose, roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*), as well as medium-sized mammals, such as brown hare (*Lepus europaeus*), red fox (*Vulpes vulpes*) and martens (*Martes* spp.) (Nadleśnictwo Jabłonna 2013).

In 2009, 478 poles with red wildlife warning reflectors (patented by Swareflex company, Swareflex GmbH, Vomp, Austria) were mounted along the monitored stretch of railway tracks. The poles were installed every 16 m on both sides of tracks, at distance of three metres from tracks. The height of poles was 1.50 m above the top of the tracks and 2.15 m above the ground. The red Swareflex wildlife warning reflectors (two-sided) were mounted on the top of each pole and turned to the railway-side (Fig. 2). They were supposed to reflect the light of headlights of a passing train away from the railway tracks at night.

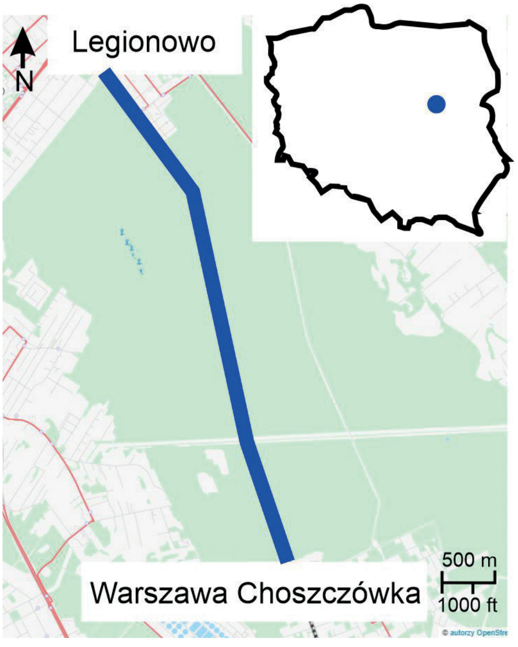

Figure 1. The stretch of E65 railway line (blue line) between Warszawa Choszczówka and Legionowo, where wildlife warning reflectors were installed and the monitoring conducted, and the placement of the study area (blue dot) on a contour map of Poland (source OpenStreetMap, modified).

Figure 2. One of the poles with red wildlife warning reflector installed along stretch of E65 railway line to mitigate animal–train collisions.

Materials ans methods

Data collection

Over the length of 2.1 km railway tracks, we monitored the reactions of animals to the trains, from August 2010 till March 2011, using ten sets of VIVOTEK digital video cameras of two megapixel resolution, equipped with motion-sensors (i.e. each case of presence of an animal on the side of the tracks triggered the video recording) and additional two infra-red illuminators. Each set (the video camera, with infra-red illuminators) was mounted on a power-line pole, two sets approx. 210 m apart from each other (Fig. 3). At half the distance between them, an additional illuminator was mounted. The cameras were turned to one direction. To ensure that the whole stretch was monitored, the view range of each digital camera was as long as 250 m (i.e. approx. 40 m longer than the distance between the two cameras), thus a video from the camera showed the next camera pole (Fig. 4). Therefore, we assigned each observation to the nearest camera, so even if an animal could be potentially registered by two cameras, only one record was taken into account. Additionally, it was possible to monitor the immediate vicinity of the rail line up to approximately 15 m from the tracks on both sides. Recorded videos were analysed using the Milestone XProtect Viewer programme.

We collected data between 1 August 2010 and 30 March 2011. From 1 August 2010 to 8 February 2011, reflectors were active (uncovered). Then, for the control period, we covered them with black plastic for the next two months (9 February – 30

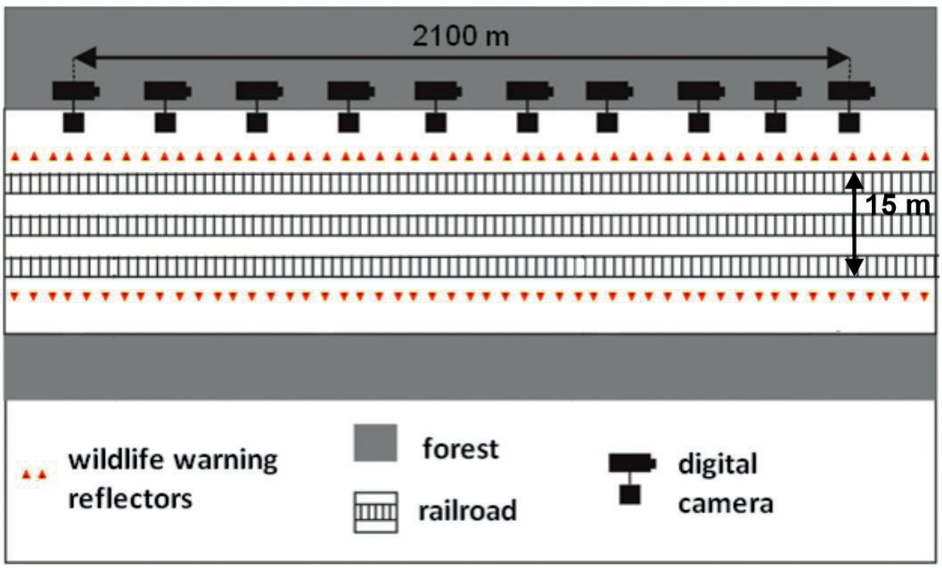

Figure 3. Deployment of the array of digital cameras along the studied E65 rail line, where wildlife warning reflectors where tested.

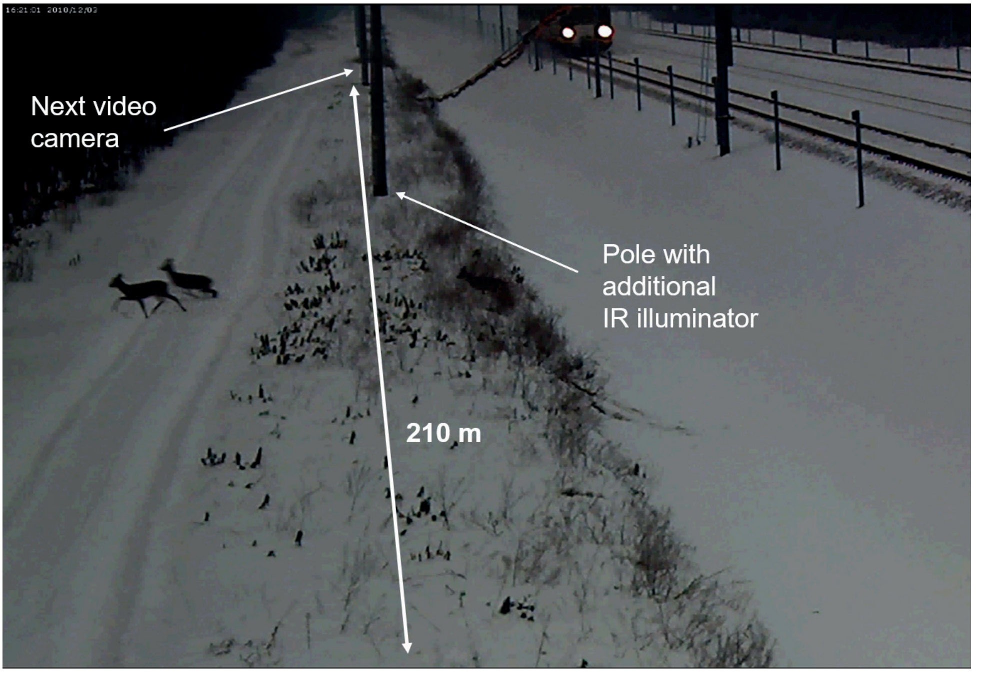

Figure 4. View from a digital camera set at the monitored stretch of E65 railway line, where wildlife warning reflectors were tested: an escape of two roe deer before an oncoming train is shown. The view from one camera extends beyond the pole with the next video camera to ensure that the whole stretch (marked with the white two-arrow line) is monitored.

March 2011), to simulate “non-active” reflectors. We registered all wildlife and train interactions (i.e. cases of animal presence near the railway tracks associated with a train passage). Animals were not marked. Each recorded sighting was counted as the presence of a single specimen or a group of animals of a given species. We differentiated two reactions of animals to a passing train: (1) escape from the track into the forest; (2) no reaction – continued foraging, a break in foraging activity or raised head. We calculated an escape time from an oncoming train as the number of seconds between the moment when an animal started to escape and the moment when a train passed the place where the animal had been standing.

For each record, we distinguished time of a day – day or night – where day was the time between sunrise and sunset and night was the time between sunset and sunrise.

Data analysis

We explored the probability of escape from an oncoming train, modelled as a logistic regression, using the reaction to the train (escape = 1, no reaction = 0) as the binary response variable. We used species, time of a day, status of reflectors (covered/uncovered) and interaction between species and time of a day and interaction between species and status of reflectors as explanatory variables. We used camera_ID as a random effect. We used Akaike Information Criterion (AIC) to evaluate the fit of models.

Then we used linear mixed-effects models to find factors affecting time of escape to an oncoming train. We used, as an exploratory variable, a combination of time of a day and status of reflectors, with three categories: (1) day (regardless of whether reflectors were covered or uncovered), (2) night with uncovered reflectors and (3) night with covered reflectors. Again camera_ID was used as a random effect. Observations for the day time were pooled together when reflectors were covered and uncovered because wildlife warning reflectors are only effective during the night, when the reflection from the train lights is visible in contrast to the dark surroundings (Benten et al. 2018a; Werka, unpubl. data).

All analyses were performed using R (v.4.1.1, R Core Team 2021) and 'lme4' package (Bates et al. 2015). Logistic regression models were fitted using the 'glmer' function with a binomial error. The linear mixed-effect model was fitted using 'lmer' function.

Results

In total, 729 observations of wildlife and train interactions were registered. A majority of these observations were recorded at night (n = 539). We recorded presence of four wild species (i.e. roe deer, brown hare, red fox and wild boar), as well as domestic cat (*Felis catus*) and domestic dog (*Canis familiaris*) and some unrecognised species (Table 1). Roe deer, red foxes and brown hares were observed most frequently, i.e. 463, 122 and 117 cases, respectively and we did further analysis only for those three species.

Probability of escape

Amongst four built models (including the null model), the one that included species, status of reflectors and interaction between species and status of reflectors was the weakest, i.e. had the highest Akaike Information Criterion (Table 2). This means that the status of reflectors (covered/uncovered) was not important in the explanation of changes in reaction of the investigated three species to an oncoming train. The inclusion of time of a day as another variable improved the fit of a model. The model selection procedure showed that the model, including species, time of a day, status of reflectors and interactions between species and status of reflectors and between species and time of a day, with camera_ID as a random effect, had the lowest Akaike Information Criterion (Table 2) and was selected as an optimal model.

The reactions of red fox and roe deer to an oncoming train were compared to reactions of brown hare. The probability of brown hare and red fox escaping from an oncoming train during day and night was similar when the reflectors were covered and uncovered (Table 3). The probability of escape of brown hare from an oncoming train equalled 59% (reflectors covered) and 54% (uncovered) during day and 69% (covered)

Table 1. Animal species registered at the stretch of E65 railway line monitored with digital cameras, between 1 August 2010 and 30 March 2011 and in times of different wildlife warning reflector status (i.e. active – uncovered and non-active – uncovered).

	Reflectors		
	Covered	Uncovered	In total
Roe deer (*Capreolus capreolus*)	33	430	463
Brown hare (*Lepus eauropaeus*)	13	109	122
Red fox (*Vulpes vulpes*)	11	106	117
Wild boar (*Sus scrofa*)	3	4	7
Domestic cat (*Felis catus*)		7	7
Domestic dog (*Canis lupus familiaris*)	3		3
Unrecognised species		10	10
	63	666	729

Table 2. Akaike Information Criterion (AIC) for models.

Model	AIC
species + time of a day + status of reflectors + species*time of a day + species*status of reflectors	890.02
species + time of a day + status of reflectors + species*status of reflectors	910.07
null model (with camera ID as a random effect)	932.96
species + status of reflectors + species * status of reflectors	935.87

Table 3. Model output for the probability of animal escape from an oncoming train. The intercept stands for brown hare reaction to an oncoming train during the day.

	Estimate	Std. Error	z value	P value
Intercept (brown hare, day, covered reflectors)	0.357	0.881	0.405	0.69
Red fox	-0.374	1.075	-0.348	0.73
Roe deer	1.727	1.003	1.722	0.09
Night	0.450	0.716	0.629	0.53
Uncovered reflectors	-0.217	0.684	-0.317	0.75
Red fox*night	-0.248	0.816	-0.305	0.76
Roe deer*night	-2.448	0.784	-3.123	0.002
Red fox*uncovered reflectors	0.015	0.961	0.015	0.99
Roe deer*uncovered reflectors	0.194	0.802	0.242	0.81

and 64% (uncovered) during night. The likelihood that red fox escaped from an oncoming train equalled 50% (reflectors covered) and 45% (uncovered) during day and 54% (covered) and 50% (uncovered) during night. Only the roe deer model output showed differences between probability of escaping from an oncoming train during day (89%) and night (52%), regardless of reflectors were covered and uncovered (Table 3).

Time to escape

We collected enough data only for roe deer to compare the time of escape from oncoming trains. Neither time of a day nor status of reflectors affected time of escape of roe deer from an oncoming train. The mean time of roe deer reaction to an oncoming train during a day (intercept) was 6.4 seconds before train arrival and this did not

Table 4. Model output for the timing of roe deer escape from an oncoming train. The intercept stands for roe deer timing of escape during day (for covered and uncovered wildlife warning reflectors).

	Estimate	Std. Error	t value	P value
Intercept (day)	-6.438	1.123	-5.733	< 0.0001
Night - covered reflectors	-1.118	3.198	-0.350	0.73
Night - uncovered reflectors	1.806	1.430	1.263	0.21

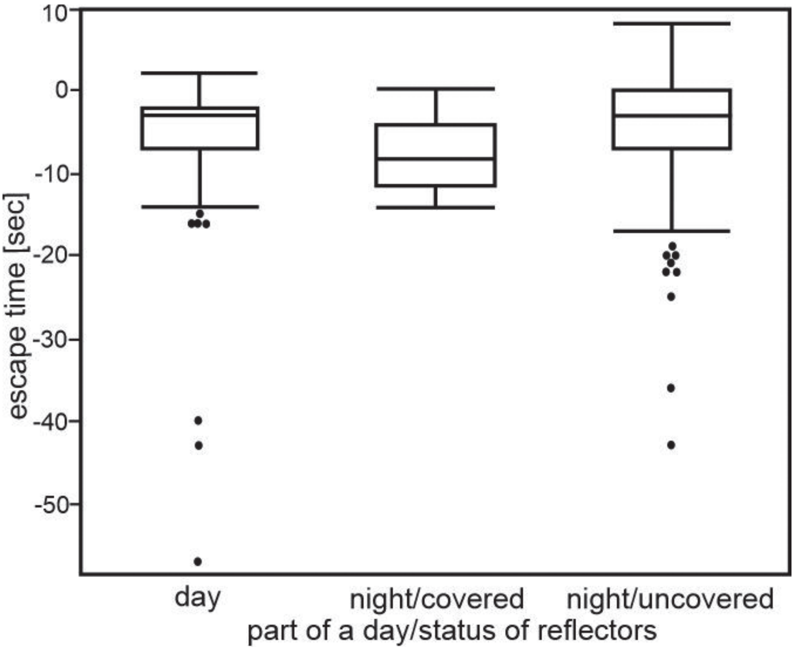

Figure 5. Time of roe deer escape from an oncoming train during day and at night when reflectors were either covered or uncovered. Negative values show that an animal escaped before a train arrived, "0" is the moment when the train passed the animal position and positive values refer to cases when animals escaped after the train had passed the place where they had been standing.

differ from time of roe deer escape during night when reflectors were either covered (mean 7.5 seconds before train arrival) or uncovered (mean 4.6 seconds before train arrival) (Table 4, Fig. 5).

Discussion

Although wildlife warning reflectors were designed primarily to reduce ungulate-vehicle collisions, they are also implemented worldwide to reduce risk of vehicle collisions with other wildlife (for example, see Ramp and Croft 2006). In our study on the effectiveness of the reflectors, we investigated reaction of three mammal species, brown hare, red fox and roe deer, to an oncoming train. According to our findings, roe deer tended to escape from an oncoming train more often than brown hares and red foxes. Nevertheless, the influence of reflectors on reaction of animals to an oncoming train was not confirmed. Time of a day was more meaningful; however, the probability of escape from an oncoming train at night (i.e. at times when reflectors were supposed to work) was not different from that recorded during a day in the case of red fox and brown hare, while it was even lower than during a day in the case of roe deer. We also compared the time of roe deer escape from an oncoming train during days (pooled data for reflectors covered and uncovered) and nights when the reflectors were either covered or uncovered. Again, the analysis did not prove that wildlife warning reflectors modified roe deer behaviour near railways. The mean time of escape of roe deer from the train ranged from approximately 4 to 7 seconds and did not differ at day and night or when reflectors were either active or non-active.

Our findings stand in line with other research conducted on roads, which did not show the clear effect of warning reflectors on the number of wildlife-vehicle collisions (e.g. Zacks 1986; Waring et al. 1991; Brieger et al. 2017; Kämmerle et al. 2017; Benten et al. 2018a; Riginos et al. 2018) or their potential to modify animal behaviour (e.g. Waring et al. 1991; D'Angelo et al. 2006; Benten et al. 2019). On the other hand, Ujvári et al. (1998) found some flight response by deer to warning reflectors, which decreased after a few days, probably due to familiarisation by the animals. Similar findings were presented by Benten et al. (2019), showing that ungulates were more likely to leave the roadside when warning reflectors were present, but the effect of reflectors expired after less than one month (approx. 17 days).

Previous studies on wildlife warning reflectors indicated also that the colour of reflectors might affect their effectiveness (Riginos et al. 2018). Many different colours of reflectors are available, with red and white or amber being the most popular (Benten et al. 2018a). In our research, the red reflectors were used. While people perceive red as a warning signal, most mammals are unable to detect that colour (Benten et al. 2018a). It might be argued that warning reflectors in an alternative colour could have been more effective on the railway lines. Nevertheless, lack of effectiveness of wildlife warning reflectors presented in our studies is in line with previous studies that examined red (Zacks 1986; Waring et al. 1991; Riginos et al. 2018), blue and multi-coloured wildlife warning reflectors (Brieger et al. 2017; Kämmerle et al. 2017; Benten et al. 2018b). Additionally, D'Angelo et al. (2006) tested four colours of reflectors (red, white, blue, amber) and revealed that the colour of reflector had no influence on the effectiveness of wildlife warning reflectors.

In our study, we did not find any differences between reaction to an oncoming train during day and night for red fox and brown hare, while roe deer escaped from an oncoming train more often during the day (when light from reflectors is far less likely to be visible due to ambient light). Ungulate prey can use increased vigilance to reduce their risk of predation, but various factors (i.e. large predators, human disturbances) will modify this response (Proudman et al. 2020). During daytime, the vigilance of animals might be higher (Lima and Bednekoff 1999), also as a response to disturbance from humans (Proudman et al. 2020). Indeed, our study area is located close to the borders of a large city and is heavily penetrated by human and (also free-ranging) dogs.

It may have been best to evaluate the effectiveness of a method preventing animal-vehicle collisions with a Before-After-Control-Impact (BACI) research design. Yet, in this case, we were not able to apply this as wildlife warning reflectors were already mounted along railway lines before we could test them. Therefore, we decided to deactivate them (i.e. cover) to provide control samples for the test period (Schafer et al. 1985; Barlow 1997; Riginos et al. 2015; Riginos et al. 2018). Unfortunately, due to unforeseen circumstances (part of the equipment was stolen and impossible to restore), this part was abandoned after two months (as opposed to the intended half a year). This resulted in a smaller sample size for the control period, which might have biased the results. The other factor that needs to be acknowledged is that seasonality was not accounted for in our research, i.e. testing and control periods were during different months, i.e. control period was conducted at the beginning of the year (February-March), while the test period of research (active reflectors) was registered during autumn and beginning of winter (August–January), during seasonal migration of animals caused by the rut/mating season (Krauze-Gryz et al. 2017). Again, low samples in a control period might also be connected with the seasonal changes in animal behaviour. Nevertheless, we believe that, even with those shortcomings, our results are important as they clearly showed lack of any influence of reflectors on animal behaviour.

Conclusions

Our study did not show reflectors being able to modify animal behaviour to an oncoming train. Roe deer more often escaped as a response to an oncoming train at days than at nights (contrary to what was expected, i.e. reflectors working at night) and the flight behaviour (i.e. time of escape) did not change between periods when the devices were active or inactive. Based on our results, we conclude that (red, as used in our study) wildlife warning reflectors were not an effective tool for mitigating wildlife–vehicle collisions on railways.

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