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Effectiveness of blue wildlife warning reflectors for avoiding wildlife accidents on rural roads

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Abstract

In a study published in 2007 on the effectiveness of white, red and acoustic reflectors, no discernible effect on accidents involving wildlife was ascertained. After this study was published, experts increasingly stated that blue reflectors had a positive impact on wildlife accidents. The new study is the first prospective and randomized crossover study planned, conducted and analyzed to examine the effectiveness of wildlife warning reflectors. On each of the stretches of road in the study, the occurrence of wildlife accidents was recorded both with and without wildlife warning reflectors. In addition, the other question of whether, for example, infrastructural, road space-related, land use-specific or animal-specific parameters can have a significant impact on wildlife accidents was also examined.

A reduction in wildlife accidents after wildlife warning reflectors were installed on all stretches of road in the study was neither discernible nor statistically demonstrated. That also applies to each reflector type observed.

Keywords: wildlife accidents; wildlife warning reflectors; accident costs; animal behavior; wildlife crossings; wildlife fencings

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1. Background and objectives

Wildlife accidents represent only a relatively minor risk of injury for road users compared to accidents as a whole on German roads. Wildlife accidents happen almost exclusively on roads outside of built-up areas. 2,334 wildlife accidents involving injury were recorded by the police on these roads in 2017. That corresponds to around 2.5 percent of all accidents involving injury on roads outside of built-up areas. 10 people were killed, 561 suffered serious injuries, and 2,121 suffered minor injuries (table 1). Around 96 percent of these accidents occurred on roads outside of built-up areas that are not part of the autobahn (freeway) network.

Table 1. Wildlife accidents and accident occurrence on roads outside of built-up areas in 2017

Accident characteristics	**Accidents and accident consequences on roads outside of built-up areas**		
	All accidents	**Wildlife accidents**	
	Number	**Number**	**Percentage [%]**
Accidents involving injury	**95,094**	**2,334**	**2.5**
Of which …	141,734	2,692	1.9
… Casualties			
… Fatalities	2,204	10	0.5
… Serious injuries	31,547	561	1.8
… Minor injuries	107,983	2,121	2.0

Source: Federal Statistical Office (Destatis), Fachserie 8 Reihe 7, 2018

The great majority of wildlife accidents, however, are accidents involving damage to property, which are often not recorded by the police. This constitutes a very big gap in the official statistics.

The number of damage claims made to car insurers under comprehensive insurance policies as a result of wildlife accidents increased in the 10 years up to 2017 by 14 percent to around 275,000. The associated insurance benefits paid out increased in the same period by around 50 percent to 744 million euros (figure 1). Wildlife damage now accounts for the second-most damage claims in comprehensive motor insurance after glass breakage. Wildlife damage to vehicles without comprehensive insurance is generally not recorded and thus does not appear in the accident statistics.

According to the wildlife accident statistics of the Deutscher Jagdverband, a hunting association, depending on the type of animal, up to 20 percent of wild animals that are killed are not killed as a result of hunting. It can be assumed that most of them are killed in collisions with vehicles on the roads. Given the growing volume of traffic, this number can be expected to continue to rise in the coming years. The countermeasures implemented in recent years are generally very cost-intensive (e.g. fencing and viaducts for wildlife) or have had little success (e.g. white and red reflectors and signs warning of wildlife crossing the road).

In a study published by the UDV (German Insurers Accident Research) in 2007 on the effectiveness of white, red and acoustic reflectors, no discernible effect on accidents involving wildlife was ascertained. After this study was published, experts increasingly stated that blue reflectors had a positive impact on wildlife accidents. However, the manufacturers of these reflectors have not conducted a broad-based scientific study demonstrating that their products bring about a statistically significant reduction in wildlife accidents.

The UDV therefore designed and funded a new study, which was conducted by the University of Göttingen in tandem with the University of Zurich. The central question to be clarified was whether the use of blue or multicolored reflectors can reduce the number of wildlife accidents with lasting effect. In addition, the secondary question of whether, for example, infrastructural, road space-related, land use-specific or animal-specific parameters can have a significant impact on wildlife accidents was also to be examined.

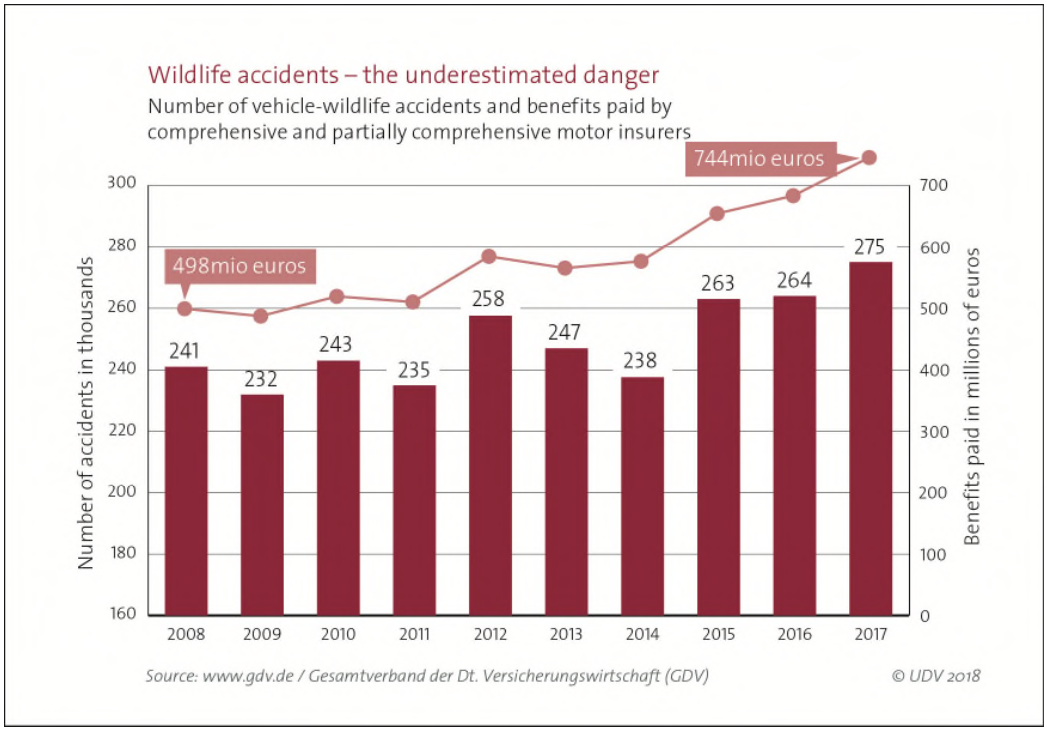

Fig. 1 Results of studies on the effectiveness of wildlife warning reflectors

2. Summary of previous studies

An intensive analysis was conducted of the national and international scientific literature. This consisted of 76 studies, dissertations and other reports (e.g. conference transcripts) on the subjects of wildlife accidents, wildlife warning reflectors and measures designed to prevent wildlife accidents. In addition, species-specific migrations of wild animals and their road-crossing behavior was researched.

It became clear that very different results on the effectiveness of wildlife warning reflectors have been reported (figure 2). The differences in the findings are due not least to methodological reasons. Not all approaches allow clear hypotheses to be tested statistically. An effective reduction of wildlife accidents by particular types or colors of reflectors has not yet been demonstrated statistically. Moreover, many of the studies had a small sample size. Both of these aspects are essential if reliable results are to be obtained.

In a study of the German Federal Highway Research Institute (BASt), the operating principle of the lighting of nine different currently commercially available optical wildlife warning reflectors was tested at TU Dresden (Schulze et al., 2017). Given that on average less than 5 percent of a reflector's surface is actually reflective, the warning effect of all these products for wildlife at the side of the road is so slight that it scarcely exceeds the illumination provided by the headlights of the approaching vehicles. The study thus comes to the conclusion that none of the tested optical reflectors is capable of generating visual stimuli that are sufficiently perceptible for wildlife. Enhancing the technology (different colors, stronger headlights) also cannot be expected to bring about an effective solution.

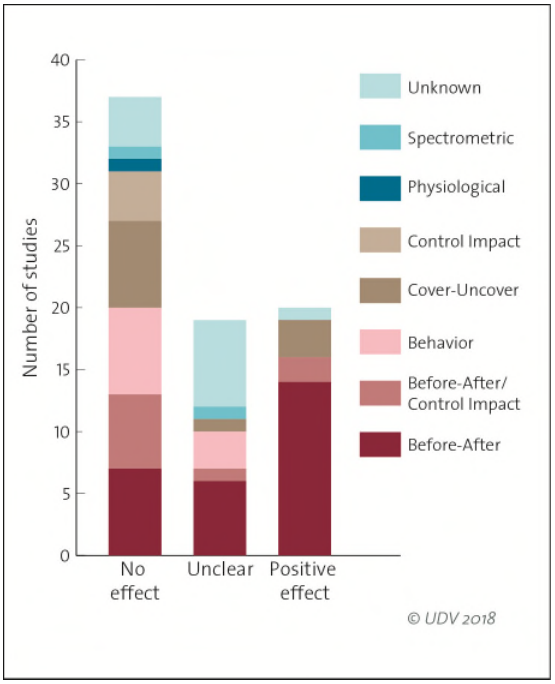

Fig. 2 Results of studies on the effectiveness of wildlife warning reflectors

3. Methodology and sample

This study is the first prospective and randomized crossover study planned, conducted and analyzed to examine the effectiveness of wildlife warning reflectors. On each of the stretches of road (with low and high wildlife accident densities) in the study, the occurrence of wildlife accidents was recorded by the police both with and without wildlife warning reflectors. As a result, it was possible to eliminate the influence of external factors on the occurrence of wildlife accidents such as wildlife density, traffic volume, speed limits, road geometry, rules of the road, width and use of the space next to the road or particular black spots and to specifically evaluate the causal effect of the wildlife warning reflectors. The setup for the stretches of road (first year with wildlife warning reflectors and second year without or vice versa) was randomized in order to eliminate systematic distortion of the results.

Based on the lack of evidence in the literature for the effectiveness of wildlife warning reflectors, the study was planned with the aim of providing statistically reliable proof of their ineffectiveness. Ineffectiveness was defined in advance of the study as a reduction of less than 10 percent in wildlife accidents as a result of using wildlife warning reflectors. Given these assumptions, the required number of cases of approximately 150 stretches of road, each two kilometers long, as of which statistically reliable statements could be made, was calculated using computer simulations.

The effectiveness of three widespread commercially available blue and multicolored wildlife warning reflectors was examined.

151 stretches of road in four districts in three federal states were selected in order to compensate for any regional differences in dealing with wildlife accidents:

- The district of Göttingen in Lower Saxony
- The district of Lahn-Dill in Hesse
- The district of Kassel in Hesse
- The district of Höxter in North Rhine-Westphalia

Different volumes of wildlife accidents were recorded by the police on the stretches of road studied. Before the study no wildlife warning reflectors had yet been installed. Although it was initially planned to include the

hunting community in the project in order to be able to record more of the wildlife accidents that occurred, it was decided not to do this for two reasons: it proved to be very difficult to make the data available in a standard format, and there were no comparable statistics available for the previous years and the whole district.

Reflectors were installed along half of the two-kilometer test stretches in the first year of the study (set A). Reflectors were installed along the other half in the second year of the study (set B). Figure 3 shows the different comparison options offered by the design selected for the study.

For each of the three reflector types, 50 test and control stretches of road were studied for two years each. The statistical analysis of the study was based on a Poisson mixed model customized to suit the study design for estimating the relative change to the expected number of wildlife accidents per road kilometer (wildlife accident density). In addition, other parameters that can have an influence on the occurrence of wildlife accidents were recorded and tested with regard to their statistical significance. Thermal imaging cameras were also installed on selected stretches of road in order, above all, to study the crossing behavior of wild animals on roads with and without wildlife warning reflectors.

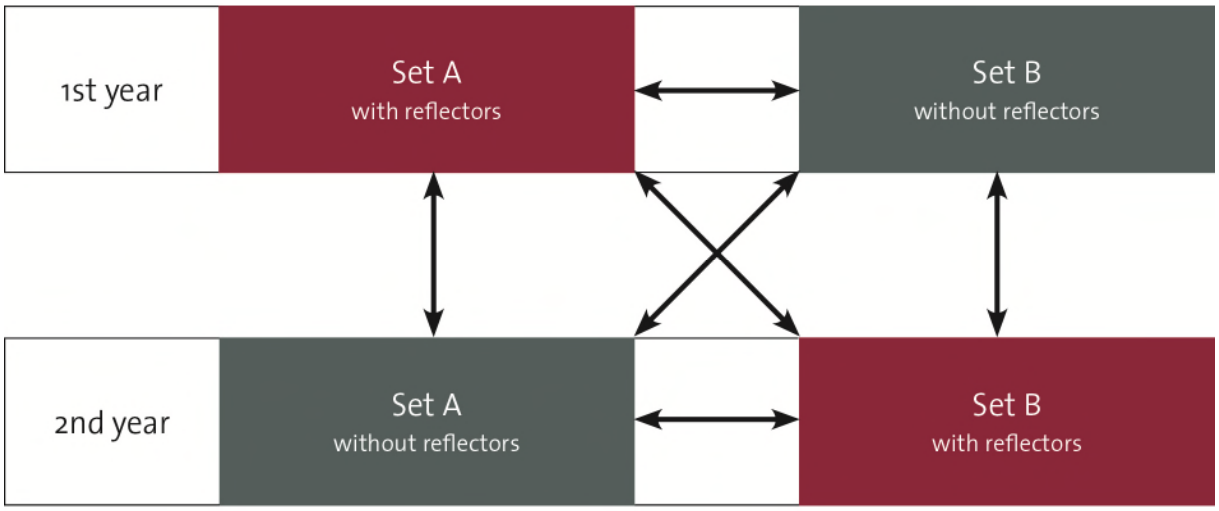

Fig. 3 Comparison of the individual sets of road with and without reflectors

4. Trends for wildlife accidents in the districts studied

A total of over 11,400 wildlife accidents were recorded by the police in the four districts during the period of the study. The numbers of accidents varied greatly depending on the time of year (figure 4).

Most wildlife accidents occurred between 6 p.m. and 7 a.m. from October to March. In the spring and summer months, the wildlife accidents occur later as the sun sets later. This is shown for the district of Göttingen in figure 5. As can be seen in the chart, sunset correlates with the risk of a wildlife accident.

Roe deer were the species most often recorded as being involved in wildlife accidents, accounting for 65 percent of the accidents in the districts studied. A total of 1,974 wildlife accidents were recorded by the police on the 151 test stretches of road in the period of the study. In both years, significantly more accidents were recorded than in the three years prior to the study.

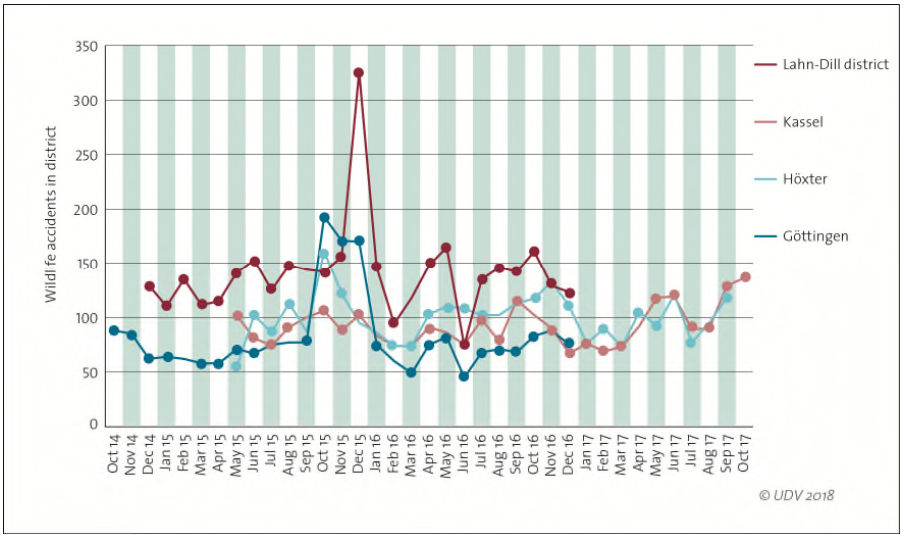

Fig. 4 Seasonal trend in wildlife accidents recorded by the police through-out the districts of Göttingen, Lahn-Dill-district, Höxter and Kassel

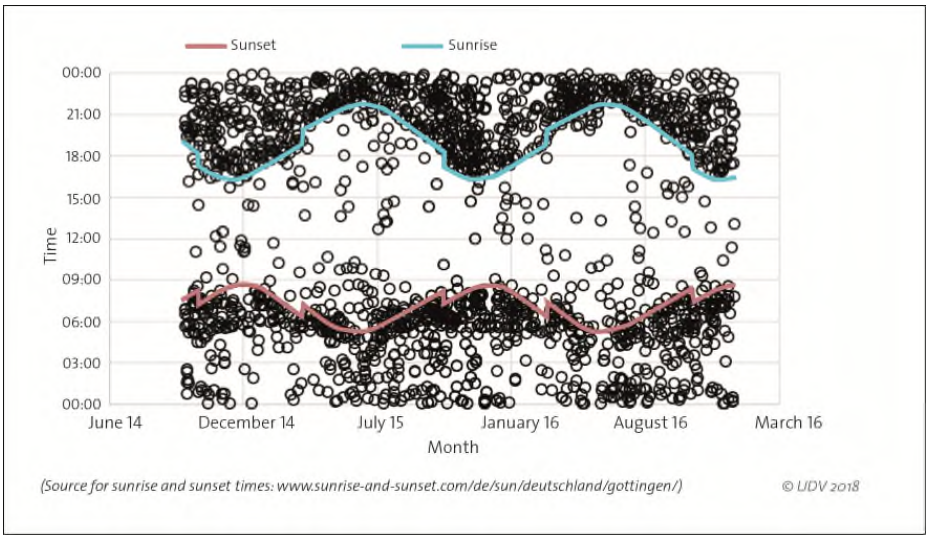

Fig. 5 Wildlife accidents recorded by the police by time and month on the stretches of road studied in the district of Göttingen

5. Effectiveness of blue and acoustic reflectors

To investigate the effectiveness of wildlife warning reflectors, the following null hypothesis was tested for the stretches of road observed: “The number of wildlife accidents occurring within a year along a particular stretch of road will not be reduced by installing reflectors.”

The statistical analysis of the results showed that the total number of wildlife accidents did not fall after wildlife warning reflectors were installed (figure 6). The Poisson mixed model used led to an estimated wildlife accident ratio (frequency of wildlife accidents with reflectors in relation to the numbers on the control stretches of road) of 1.02 with a corresponding 95 percent confidence interval (0.92, 1.12). The multiplier effect of wildlife warning reflectors compared to the passive control group (i.e. the stretches of road without wildlife warning reflectors) indicates, if anything, an average increase of 2 percent in wildlife accidents where there are wildlife warning reflectors. There is even no reflector effect when only wildlife accidents during the night-time and twilight phases are considered (times at which headlamps have to be switched on to drive).

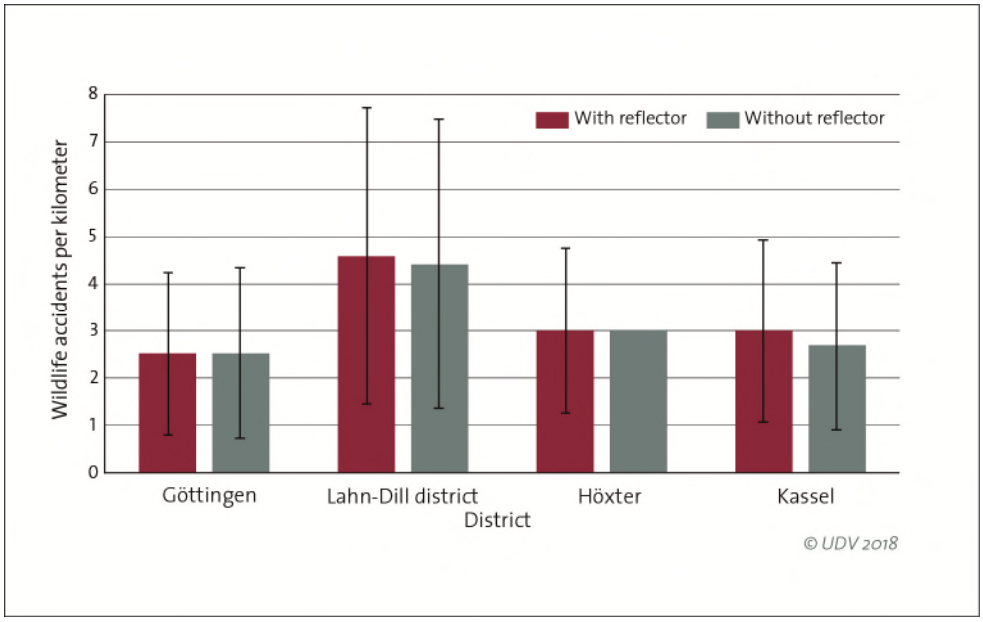

Fig 6 Number of wildlife accidents per kilometer and year with and without wildlife warning reflectors in the four districts studied

Accordingly, the hypothesis could not be rejected. In the same way, no significant effect on wildlife accidents could be demonstrated for individual optical reflector types (figure 7) or for an acoustic reflector installed together with optical reflectors (UDV, 2018; research report no. 56).

The number of wildlife accidents recorded by the police was thus not significantly affected by installing wildlife warning reflectors. That applies both to the whole sample of tested reflectors and individual reflector types.

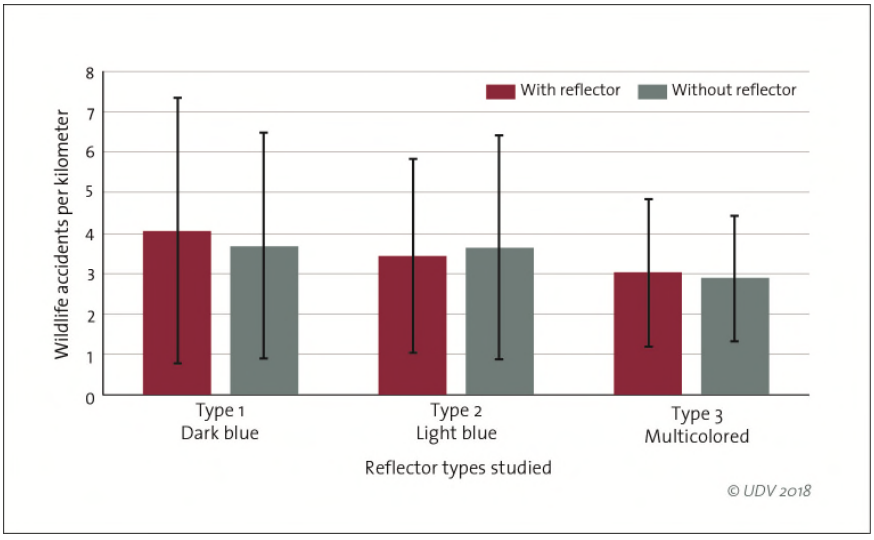

Fig 7 Number of wildlife accidents per kilometer and year on test stretches of road with the three optical wildlife warning reflectors tested

6. Influence of the parameters on wildlife accidents

The findings from the project suggest that the number of wildlife accidents depends on external and biological factors. The number of wildlife accidents is particularly high, above all, when it is dark and during the mating season of individual species. In order to be able to test this and other possible variables in terms of their significance for wildlife accidents, a Poisson regression model and then a generalized linear model were used. A total of 60 potential explanatory parameters were examined in terms of their influence on the number of wildlife

accidents. These include traffic volumes, the width of the space next to the road, tree spacing, curvatures, standard cross-sections, number of lanes, speed limits, StVO road sign number 142 (wildlife crossing), safety features, buildings near the road, topographic relief, land and forest usage types and hunting activities.
The associated research questions are:

- What variables have a significant effect on wildlife accidents?

- Do the significant variables include variables that can be modified at a reasonable cost to reduce wildlife accidents?

The results showed that, based on the sample of 151 stretches of road (with low and high wildlife accident densities), there was no statistically clear way to identify influencing factors recognized as influential by all models. That is very probably due to the large number of explanatory variables compared to the sample size. In this connection, however, it must be noted that the selection of explanatory variables to explain the frequency of accidents was not the study's primary goal. Instead, its design was based on the primary question (effectiveness of wildlife warning reflectors). The results indicate that no potential risk factors for increased numbers of accidents could be identified with certainty. It is therefore not possible to come up with proposals for measures to be taken based on them.

7. Analysis of animal behavior

In addition to recording numbers of wildlife accidents to test the effectiveness of wildlife warning reflectors, the reaction of wild animals to approaching vehicles with and without wildlife warning reflectors was recorded using thermal imaging cameras and then analyzed (figure 8).

Fig 8 Wild animals leave the roadway on the approach of a vehicle

A total of 1,070 encounters between vehicles and wild animals were recorded during the study period. 1,674 animals were observed. The following research questions are briefly answered here.

How frequently can wildlife warning reflectors have an effect on the behavior of wild animals?
In 34.6 percent of the cases, wildlife warning reflectors had no effect on the behavior of the animals, because they were either on the road or between the marker post and the road, they had already left the road and may have been facing away from the road, or they crossed the road in flight without lingering by the road beforehand.

How often do wild animals react positively (in the sense of avoiding an accident) or negatively (in the sense of increasing the risk of an accident) to approaching vehicles, and do reflectors change this behavior?
For this analysis, the behavior of 1,094 animals was observed and analyzed in situations in which wildlife warning reflectors could have influenced the animals' behavior. The proportion of positive and negative reactions of the wild animals does not differ between the two groups with and without wildlife warning reflectors. Overall, the animals reacted positively to approaching vehicles in 94.3 percent of cases and negatively in 5.7 percent of cases. There is thus no evidence that wildlife warning reflectors lead to a change in the reactions of wild animals to approaching vehicles.

Does the distance the animals flee from the road change when there are wildlife warning reflectors?
The animals left the road in 70.5 percent of all cases. The distance they fled from the road varied between 153 meters (for roe deer) and 228 meters (wild boars). There was no significant change in the distance fled by any species in the presence of wildlife warning reflectors. Wildlife warning reflectors thus had no effect on the distance wild animals fled from approaching vehicles.

Does the reaction of the animals to approaching vehicles change in the presence of wildlife warning reflectors?
In most cases, wild animals reacted differently to approaching vehicles depending on their distance from the road (rapid flight: 32.2 percent; slow movement away: 38.3 percent). They paused attentively with their heads up in 15.5 percent of the cases observed and showed no reaction to approaching vehicles in 14.0 percent of cases. The presence of wildlife warning reflectors did not change this behavior. Animals neither fled significantly more often nor moved slowly away from the road more often when wildlife warning reflectors were installed. Contrary to manufacturers' statements, the animals also did not pause attentively with their heads up in the presence of the reflectors. Wildlife warning reflectors thus had no effect on the behavior of wild animals near the road.

Does the presence of the reflectors change the behavior of the drivers?
In most cases, no reaction of drivers to the wild animals close to the road was observable (95.6 percent). In rare cases, it was observed that drivers slowed down (2.8 percent) or slammed the brakes on (1.7 percent). This did not change in the presence of the reflectors.

Do reflectors stop wild animals from crossing the road?
Wild animals crossed the road in 38.9 percent of the cases observed. This did not change in the presence of reflectors, either when the animals crossed the road when there was no vehicle in sight or when they crossed as a reaction to approaching vehicles. Wildlife warning reflectors thus did not prevent wild animals from going on the road despite approaching vehicles.
In most cases (94 percent), the reaction of wild animals was such as to reduce the risk of an accident. The animals generally moved away from the road either hurriedly or in a composed manner (70 percent of cases), noticed the vehicle (15 percent of cases) or showed no reaction (14 percent of cases). Often the animals moved away without having to cross the road. When the animals did cross the road, this was not influenced by the presence of wildlife warning reflectors. A low percentage of negative reactions by wild animals that increase the risk of an accident (5.7 percent in this study, regardless of the presence of wildlife warning reflectors) is evidently enough to result in over 275,000 wildlife accidents a year (GDV, 2018). In only a few cases were drivers observed to react to wild animals near the road by slowing down or slamming on the brakes. Wildlife warning reflectors did not change drivers' reactions. Overall, wildlife warning reflectors were found to have no effect on the behavior of animals near the road. This finding corresponds very closely to that of another new study examining the reactions of roe deer to approaching vehicles under the influence of wildlife warning reflectors (Brieger et al., 2017).

8. Summary and recommendations

The study on the effectiveness of blue wildlife warning reflectors came to the following conclusions on the basis of the three different products used on 151 stretches of road in four different districts:

- The trend of the accident occurrence in the period of the study was very heterogeneous. On some stretches there were more accidents, on others fewer.

- A reduction in wildlife accidents after wildlife warning reflectors were installed on all stretches of road in the study was neither discernible nor statistically demonstrated. That also applies to each reflector type observed.
- No change in the behavior of the wild animals was found.
- The international research results vary greatly and do not permit a general statement on the effectiveness of the reflectors.

A study carried out by TU Dresden (Schulze et al., 2017) into the lighting properties of reflectors of different colors shows that they do not reflect much light, and it therefore has to be assumed that they are ineffective.
Behavioral studies carried out by the FVA, a forestry research institute (Brieger et al. and Kämmerle et al.), indicate that blue light does not cause wild animals to react differently compared to white light and that reflectors do not change behavior.

Taken together, the findings therefore show that wildlife warning reflectors are not a suitable means of effectively reducing wildlife accidents.

Other measures will therefore have to be taken to reduce the number of wildlife accidents. The most effective means of preventing wildlife accidents is therefore likely to be the physical separation of wildlife and vehicles, as is usual on autobahns (freeways). These include wildlife fencing combined with green bridges (wildlife crossings). However, protecting wildlife crossings (with a length of around 200 meters depending on species, animal behavior and habitat) by means of electronic wildlife warning road equipment is also conceivable.

As far as vehicles are concerned, the further development of wildlife warning systems could draw drivers' attention to wild animals on or next to the roadway in good time, even in the dark, and thus get them to adjust their speed or even stop their vehicle.

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