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Animal detection systems: research questions, methods and potential applications

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Abstract

Animal detection systems detect large animals (e.g. ungulates) before they enter the road and then warn drivers that a large animal is on or near the road at that time. This paper identifies research questions related to the reliability and effectiveness of animal detection systems and suggests research methods. It also shows how animal detection systems can be applied, for example in combination with wildlife fences and wildlife under- or overpasses. Individuals involved with the development, application and evaluation of animal detection systems are encouraged to share the results of their studies, and to publish and distribute them.

Introduction

Animal-vehicle collisions affect human safety, property and wildlife. In the United States the total number of deer-vehicle collisions was estimated at more than 1 million per year (Conover et al., 1995). These collisions were estimated to cause 211 human fatalities, 29,000 human injuries and over one billion dollars in property damage a year (Conover et al., 1995). Similar figures are available from Europe. Here the annual number of collisions with ungulates was estimated at 507,000, causing 300 human fatalities, 30,000 human injuries and over one billion dollars in material damage (Groot Bruinderink & Hazebroek, 1996). These numbers are likely to have increased even further over the last decade (Hughes et al., 1996; Romin & Bissonette, 1996; Anonymous, 2003). In most cases the animals die immediately or shortly after the collision (Allen & McGullough, 1976). In some cases it is not just the individual animals that suffer. Road mortality may also affect some species on the population level (e.g. van der Zee et al., 1992; Huijser & Bergers, 2000) and some species may even be faced with a serious reduction in population survival probability (Proctor, 2003). In addition, some species also represent a monetary value that is lost once an individual dies (Romin & Bissonette, 1996; Conover, 1997).

Historically animal-vehicle collisions have been addressed by putting up signs that warn drivers for potential animal crossings. In other cases wildlife warning reflectors or wildlife fences have been installed to keep animals away from the road (e.g. Clevenger et al., 2001). However, conventional warning signs appear to have only limited effect because drivers are likely to habituate to them (Pojar et al., 1975), wildlife warning reflectors may not be effective (Reeve & Anderson, 1993; Ujvári et al., 1998), and wildlife fences isolate populations. In some selected areas wildlife fencing has been combined with a series of wildlife crossing structures (e.g. Foster & Humphrey, 1995; Clevenger et al., 2002). In most cases however, such crossing structures are limited in number and width, often because of their relatively high costs. This paper focusses on a relatively new alternative to wildlife crossing structures; animal detection systems that are located in the right-of-way. Animal detection systems detect large animals (e.g. ungulates) as they approach the road.

When an animal is detected, signs are activated that warn drivers that large animals may be on or near the road at that time. Farrell et al. (2002), Robinson et al. (2002), and Huijser and McGowen (in press) described the various system types, documented experiences with operation and maintenance, and listed their locations throughout North America and Europe.

At this time there is little to no coordination between the multiple projects that test and evaluate the reliability and effectiveness of animal detection systems. While some questions have been answered for some systems, many questions remain. This paper identifies the research questions and methods related to the testing and evaluation of animal detection systems. In addition, this paper shows how animal detection systems could be applied and integrated with other mitigation measures.

Research questions

The purpose of animal detection systems is twofold: to reduce collisions with large animals (e.g. ungulates) while still allowing for animals to cross the road so that connectivity between populations on either side of the road is maintained. In order to reduce the number of animal-vehicle collisions, animal detection systems need to detect animals reliably, and they also need to influence driver behavior such that drivers can avoid a collision. This leads to the following research topics and questions:

System reliability

- Do animal detection systems detect animals reliably?
The essence of animal detection systems is to detect animals when they approach the road. Therefore 'false negatives', i.e. an animal approaches, but the system fails to detect it, should not occur. Animal detection systems should also minimize 'false positives', i.e. the system reports the presence of an animal, but there is no animal present. Numerous false positives would result in a system that resembles a warning light that flashes constantly and that is not connected to sensors. It is equally important that animal detection systems have minimal 'downtime', for example due to broken parts or maintenance. Despite the obvious nature of these basic requirements, many animal detection systems are still in the experimental stage and suffer from a variety of such problems (Huijser & McGowen, in press).
- Are some systems better than others?
Employees from transportation agencies and other individuals need to make informed decisions when they consider purchasing and installing an animal detection system. Ideally, all available animal detection systems should be tested under the same circumstances at the same time at multiple locations that represent a wide range of road, weather and other circumstances. This would allow for the selection of the best system, given the requirements of the customer and the conditions of the site concerned. With just one exception (Gordon et al., 2001), the few projects that evaluated the reliability of animal detection systems focused on one system type only (see Huijser & McGowen, in press). In addition, these projects typically dealt with only one study site, except for Kistler (1998), and did not include a wide variety of road, weather and other conditions that may influence system performance.

System effectiveness

- Do drivers respond to the warning signals?
Driver responses such as reduced vehicle speed or increased alertness determine how effective animal detection systems are in reducing animal-vehicle collisions. Previous studies have shown that drivers do not always substantially reduce their speed in response to activated warning signs

(Muurinen & Ristola, 1999; Gordon & Anderson, 2002). Drivers may only reduce their speed when road and weather conditions are bad or when the warning signs are accompanied with a maximum speed limit sign (Kistler, 1998; Muurinen & Ristola, 1999). However, failure to substantially reduce vehicle speed under all circumstances does not necessarily make animal detection systems ineffective. Minor reductions in vehicle speed are also important since a small decrease in vehicle speed is associated with a disproportionately large decrease in the risk of a fatal accident (Kloeden et al., 1997). In addition, activated warning signs are likely to make drivers more alert. Driver reaction time to an unusual and unexpected event can be reduced from 1.5 s to 0.7 s if drivers are warned (Green, 2000). Assuming a vehicle speed of 88 km/h (55 M/h), increased driver alertness can reduce the stopping distance of the vehicle by 21 m (68 ft). However, this reduction in reaction time and stopping distance has not specifically been tested with respect to the presence of large animals in rural areas.

- Do animal detection systems result in fewer animal-vehicle collisions? Most sites with an animal detection system record the number of animal-vehicle collisions, but this information is usually not properly documented, published, and distributed. Only Kistler (1998) published on the number of animal-vehicle collisions before and after seven infrared detection systems were installed in Switzerland. These systems reduced the number of animal-vehicle collisions by 82% on average.
- Do animal detection systems provide sufficient crossing opportunities for animals? An animal detection system should modify driver behavior rather than restrict animal movements across the road. This is an important potential advantage over wildlife crossing structures that are often combined with wildlife fencing (e.g. Foster & Humphrey, 1995; Clevenger et al., 2002). However, of 26 locations with animal detection systems, six were installed in a gap in wildlife fencing (Huijser & McGowen, in press). One has to know how many gaps should be created over a certain road length to maintain sufficient connectivity across the road for the animal species concerned. It is also important to know how wide these gaps should be, and where the most effective crossing locations would be.

Research methods

The previous section described the research questions related to the reliability and effectiveness of animal detection systems. The section below describes the methods one could use to answer these questions.

System reliability

- Do animal detection systems detect animals reliably? It is important that all causes and possible remedies for potential 'false negatives', 'false positives' and maintenance or other problems or issues are properly recorded, published, and distributed among the people that are actively involved with the development, application and evaluation of animal detection systems. Huijser and McGowen (in press) presented an overview of all known problems and issues with animal detection systems as of September 2003. Since it is hard to predict what other problems or remedies might occur in the future, it is best to describe and classify these experiences on a case-by-case base. However, there are certain standard tests that one could carry out to check for potential 'false negatives' and 'false positives':

False negatives

- a. Actively trigger the system. One could use a tame individual of the species that the animal detection system was designed for ('target

species') to see if the system indeed records the presence of the individual when it approaches the road. One may have to settle for a model of the 'target species'; e.g. a domesticated species of similar size, or humans. The individual should enter the detection zone at multiple locations, for example at 10 m intervals, under a wide range of weather conditions.

- b. Incidental observations. People that travel the road regularly, such as road maintenance personnel and police officers, can contribute to the evaluation by reporting sightings of animals on the road in the road section concerned. They should record the date, time, exact location (to provide a link to the detection zone), species, and number of individuals. One could also involve the general public with this effort through various media. The travelling public could tune in to an AM radio message at the system location to learn about the system and how to report animal sightings in the area of the system by calling an automated answering service from their cell phone immediately after their observation. Most animal detection systems record all detections (date, time, detection zone, duration of the detection). Although one should carefully evaluate the reliability of observations provided by the public, these reports can be compared to detections recorded by the system to identify potential false negatives. The reports can also provide insight in how well different species, including 'non-target species', are detected, while simultaneously increasing driver attention to the system and potential animal crossings.
- c. Tracking. One could deploy sand tracking beds between the sensors to compare tracking events to detections recorded by the system (see b. incidental observations). Tracking beds that are at least 2.5 m (about 8 ft) wide can record tracks of many large animal species, including deer and bear species. The presence of a set of tracks indicates that an individual of that species must have passed through the detection zone since one last checked the bed and erased all previous tracks. One could also do opportunistic snow tracking tracking and then conduct the same comparisons. When using snow tracking events, it is important to know how much time has passed since the last snow fall in order to relate the track events to the system detection data.
- d. Monitor with IR camera and recording system. It is possible to record animals passing through the detection zone using a camera and recording system with date and time stamp. It would not only be advantageous to have an infrared (IR) system (night vision), but it would also be helpful if the system would mark the moments when animals enter the image. The latter would greatly reduce the time required to review the images. The images recorded by the camera system can then be compared to the detections recorded by the detection system (see b. incidental observations).

False positives

- e. Observation sessions. If there are numerous detections, and if one suspects that many of them are false, then one could observe the detection zone for a certain time to see whether or not an animal is really there when the system is triggered. Depending on the length of the section, this could require that several observers be simultaneously stationed to ensure that an animal is not missed. Even so, the problem remains that one cannot reassess those moments to verify if there was really no animal present in the detection zone.
 - f. Monitor with IR camera and recording system. See also d. This would allow for review of what might have triggered the system.
- Are some systems better than others?
Ideally, one would address this research question by testing different animal detection systems at the same site and at the same time. One

could also test multiple systems under the same circumstances at the same time at multiple locations that represent a wide range of road, weather and other conditions that may affect system performance. However, one may limit testing to weather circumstances that are challenging for electronics and that one expects to occur on a regular basis; for example high and low temperatures, snow, rain, high humidity levels or fog. One would not only have to evaluate potential false negatives and false positives, but also downtime and maintenance issues.

System effectiveness

- Do drivers respond to the warning signals?
One could evaluate this for two different parameters:
 - a. Vehicle speed. One could record the speed of passing vehicles when the warning lights are off and then compare them with vehicle speeds when the warning signals are activated. All other conditions should be kept as similar as possible to reduce variation. This can be addressed by having e.g. 30-minute sessions with the warning signals turned on versus turned off, assuming no major changes or events occur in one session or the other. It is important that this tested under a variety of weather conditions, for example when it is dark, rainy, icy or when visibility is limited. Only measure the speed of the first vehicle in a platoon to obtain independent speed-readings. It is preferable to record travel time over a predetermined distance from a remote location rather than using radar guns near the road because of the potential for the latter method to influence driver behavior. Finally, one must consider sample size needed to detect relatively small reductions in vehicle speeds.
 - b. Driver reaction time. One would have to use a driver simulator to evaluate whether activated warning signals result in increased driver alertness. A driver simulator could be programmed to display warning signals and animals moving onto the road in a controlled environment to evaluate whether stopping distance is shorter when the warning lights are activated. A driver simulator would also allow for the comparison of the effectiveness of various types of warning signals and text messages under a variety of road and weather conditions. Results from such research could be used to standardize such signs. Additionally, driver simulator research could optimize the number and spacing of warning signals that should be installed. The distance between warning signs should be such that the chance that a driver passes an inactivated warning sign and then encounters an animal before seeing the next (activated) warning sign is minimized. A driver simulator could also be used to evaluate the effect of signs with an enforceable or advisory speed limit that accompany the systems.
- Do animal detection systems result in fewer animal-vehicle collisions?
Road kills and animal-vehicle collisions should be recorded and reported both before and after an animal detection system is installed (comparison in time). An alternative is to select suitable control areas in the direct vicinity of an animal detection system (comparison in space). Both types of comparison have pros and cons. Comparisons in time must correct for fluctuating animal populations while comparisons in space could be influenced by variability in site conditions. A major problem is that the road sections over which animal detection systems are installed are often relatively short; only a couple of hundred meters (see Huijser & McGowen, in press). The number of large animals that used to be killed on those short road sections is relatively low, perhaps 'only' one per year. In addition, the number of road kills can vary substantially from year to year at a specific location. Combined with the fact that most projects only collect data from one location for a few years, it is hard to be able to show a potential statistically significant difference in the number of animal-vehicle collisions before and after a system is installed and activated. Long road sections with animal detection systems at multiple locations and monitoring over many years can help overcome these issues. An

alternative is that the road kill and animal-vehicle collision data are combined for different systems from different locations. Such a meta-analysis would show whether animal detection systems, regardless of the system type and manufacturer, reduce the number of animal-vehicle collisions.

- Do animal detection systems provide sufficient crossing opportunities for animals?
One could base the locations and road lengths that need to be accessible for wildlife on historical road kill data and/or actual or modeled wildlife movements through the area. These data are of course species and site specific. These areas should not have wildlife fencing, and one could install an animal detection system along these road sections.

Possible applications

Animal detection systems can be used without wildlife fencing (Fig. 1a) or in combination with wildlife fencing (Fig. 1b). Crossing opportunities for animals and the resulting connectivity between populations on either side of the road, are much reduced if wildlife fencing is contiguous over long distances with only a few gaps. Another drawback of gaps (crossing areas) in fences, and the ends of wildlife fencing, is that animals could end up in the right-of-way, trapped between the fences. Providing one-way exits such as jump-outs can help address this potential problem. On the other hand, a few short crossing areas may be safer than road sections where animals can cross anywhere. Although fence maintenance costs should not be underestimated (see e.g. Clevenger et al., 2002), equipment, installation, and maintenance costs for animal detection systems could be less if installed at fence gaps rather than across longer sections of unfenced road. Limited fencing may be used to funnel animals through a relatively short road section with an animal detection system (Fig. 1c). Animal detection systems could also be used to detect animals that cross at the end of a section of wildlife fencing (Fig. 1d), potentially in combination with under- or overpass installations for animals (Fig. 1e).

Discussion and conclusion

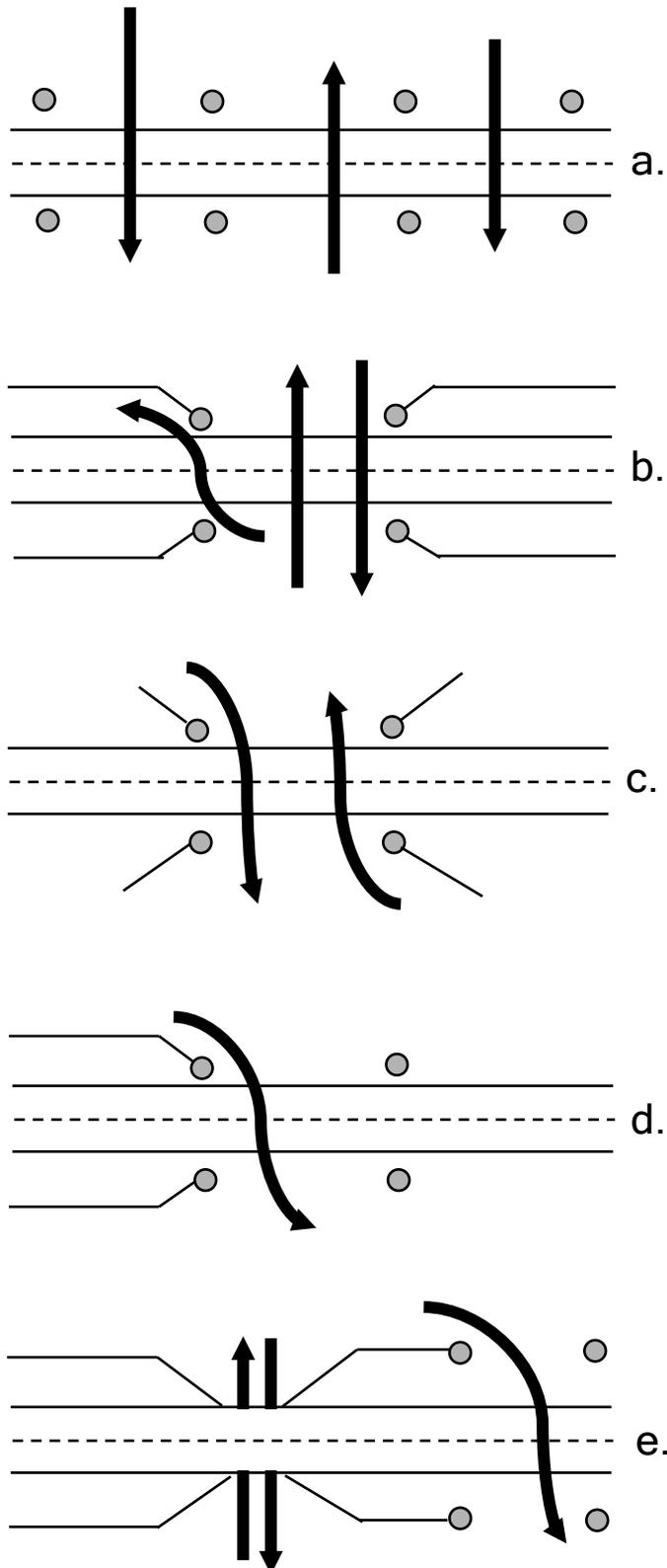
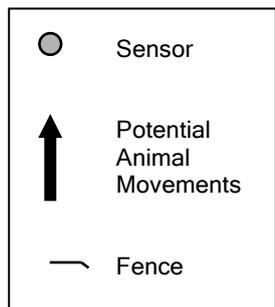
Projects that evaluate the reliability and effectiveness of animal detection systems typically address one or more of the research questions listed in this paper. However, there has been little or no coordination between individual projects, and the results often remain anecdotal and unpublished.

While projects that evaluate individual animal detection systems remain valuable and continue to contribute to the existing knowledge, this research area can benefit by expanding beyond this limited scope. The first step is to compare different animal detection systems from different vendors under the same conditions. Such a test site would have to be challenging, exposing the systems to high and low temperatures, snow, rain, high humidity levels and fog.

Combining results from different studies has led to new research questions about how road and weather conditions, and signage types influence driver responses. A driver simulator could enable researchers to test the effect of a variety of conditions on vehicle speed, driver reaction time, and other driver responses in an ethical and responsible way.

Employees from transportation agencies and other individuals involved with animal detection systems should carefully evaluate whether an animal detection system is an appropriate mitigation measure given their requirements and the conditions at the site concerned. It is important to be specific about what the problem is and what one wishes to mitigate for before deciding on what measures should be taken. For example, if one is concerned about a wide range of species, including small and medium sized mammals, then wildlife under- or overpasses combined with wildlife fences may be a

Figure 1: Schematic representations of possible applications of animal detection systems. a. System installed over a relatively long road section without wildlife fencing; b. System installed in a gap in a wildlife proof fence; c. Wildlife fences funnel the animals through a road section with a system; d. System installed at the end of a fence; e. System installed at the end of a fence that aims to guide the animals through an underpass.



better option as animal detection systems are usually designed to detect large ungulates only (Huijser & McGowen, in press). In addition, animal detection systems still require animals to cross an open area with unnatural substrate (pavement), and some species will remain isolated on either side of the road. It is also important to carefully review how one would like to apply an animal detection system, and whether it should be installed in combination with wildlife fencing.

I conclude that the science behind the evaluation of the reliability, effectiveness and potential applications of animal detection systems would greatly benefit if data from individual projects are combined and if new research questions are identified and addressed. Lastly, we encourage individuals involved with the development and evaluation of animal detection systems to publish and distribute the results of their studies.

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