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THE RELIABILITY OF TWO NEW ANIMAL DETECTION SYSTEMS AND RECOMMENDED REQUIREMENTS FOR SYSTEM RELIABILITY

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ABSTRACT

Animal-vehicle collisions affect human safety, property, and wildlife, and the number of animal-vehicle collisions has increased in many regions across North America. Animal detection systems can help reduce the number of wildlife-vehicle collisions and allow for safe crossing opportunities for wildlife. These systems detect large animals when they approach the road and once a large animal has been detected, warning signs are activated. Drivers can then respond by becoming more alert, reducing the speed of their vehicle, or both. For animal detection systems to be effective in reducing collisions, reliable systems are essential. For a previous project we investigated the reliability of nine systems from five manufacturers. The current study reports on the reliability of two new systems: 1. a buried cable that detects changes in an electromagnetic field when large animals walk over the cable and 2. a third generation break-the-beam system that uses microwave radio signals. The systems were investigated for their reliability in a controlled access test facility near Lewistown, Montana. The two new systems were also installed along real roadsides; the buried cable system was installed along Hwy 160 near Durango, Colorado, and the microwave radio signal break-the-beam system was installed along Hwy 3 near Fort Jones, California. At the test facility near Lewistown, Montana, we used horses, llamas, and sheep as a model for wild ungulates. The animals roamed in an enclosure and data loggers recorded the date and time of each detection for both systems. Animal movements were also recorded by six infrared cameras with a date and time stamp. By analyzing the images and the detection data in different seasons, researchers were able to investigate the reliability for each system. The percentage of false positives (i.e., a detection is reported by a system but there is no large animal present in the detection zone) was relatively low for both systems ($\leq 0.5\%$). However the percentage of false negatives (i.e., an animal is present in the detection zone but a system failed to detect it) differed substantially (1.9-16.8%). The percentage of intrusions (i.e., animal intrusions in the detection area) that were detected also varied substantially (88.6-99.5%). The results suggest that one of the two detection systems was quite reliable in detecting large mammals with few false positives and false negatives, whereas the other system had relatively many false negatives, mostly because of downtime. When we compared the reliability data to the recommended performance requirements that were obtained through interviews with three stakeholder groups we found that one of the two systems tested met the recommended requirements, while the other did not. Based on the results we know that some systems are quite reliable and may be considered for implementation along a roadside where they can be investigated for their effectiveness in reducing collisions with large wild mammals. However, experiences with installation, operation and maintenance suggest that the robustness of animal detection systems may have to be improved before the systems can be deployed on a large scale.

INTRODUCTION

Animal-vehicle collisions affect human safety, property, and wildlife, and the number of animal-vehicle collisions has been increasing in many regions across North America (Huijser et al. 2007). Here we investigate a relatively new mitigation measure aimed at reducing animal-vehicle collisions while allowing animals to continue to move across the landscape. We evaluated the reliability of a range of different animal detection technologies from different manufacturers.

Animal detection systems detect large animals (e.g., deer (*Odocoileus* spp.), pronghorn (*Antilocapra americana*), elk (*Cervus elaphus*) and moose (*Alces alces*)) as they approach the road (see reviews in Huijser et al. 2006; 2009a). When an animal is detected, signs are activated, warning drivers that large animals may be on or near the road at that time. Previous studies have shown variable effects of activated warning signs on vehicle speed: substantial decreases in vehicle speed (≥ 5 km/h (≥ 3.1 mi/h)) (Kistler 1998; Muurinen and Ristola 1999; Kinley et al. 2003; Gagnon et al. 2010); minor decreases in vehicle speed (< 5 km/h (< 3.1 mi/h)) (Kistler 1998; Muurinen and Ristola 1999; Gordon and Anderson 2002; Kinley, et al. 2003; Gordon, et al. 2004; Hammond and Wade 2004; Huijser et al. 2009a); and no decrease or even an increase in vehicle speed (Muurinen and Ristola 1999; Hammond and Wade 2004). This variability of the results is likely related to various conditions (see review in Huijser et al. 2009a):

- The type of warning signal and signs.
- Whether the warning signs are accompanied with advisory or mandatory speed limit reductions.
- Road and weather conditions.
- Whether the drivers actually see an animal.
- Whether the driver is a local resident.
- Perhaps the road length of the zone with the animal detection system and the road length that the warning signs apply to (the more location specific the better).
- Perhaps also cultural differences that may cause drivers to respond differently to warning signals in different regions.

Activated warning signs may also result in more alert drivers, which can lead to a substantial reduction in stopping distance: 20.7 m (68 ft) at 88 km/h (55 mi/h) (review in Huijser et al. 2009a). Finally, research from Switzerland has shown that animal detection systems can reduce ungulate-vehicle collisions by as much as 82 percent (Mosler-Berger and Romer 2003). In Germany collisions with large mammals were reduced by more than 80% (Strein 2010). In Montana a reduction of 58% was recorded (Huijser et al. 2009a) and data from Arizona showed a reduction of 97 percent (Gagnon et al. 2010).

Before animal detection systems can be effective, they must be able to detect large animals reliably. Therefore it is important to know how reliable animal detection systems are when detecting large animals and to establish minimum norms for system reliability. Until now, measuring and comparing the reliability of different animal detection systems has been problematic due to the following factors:

- Most systems have not been properly studied, or the results have not been published.
- Different studies have evaluated systems with regard to different parameters.
- Different studies used different methods.
- Different systems have been evaluated under varying conditions (e.g., varying road and climate conditions).

For a previous project we investigated the reliability of nine systems from five manufacturers (Huijser et al. 2009a; 2010). The current study reports on the reliability of two new systems: 1. a buried cable that detects changes in an electromagnetic field when large animals walk over the cable and 2. a third generation break-the-beam system that uses microwave radio signals. The systems were investigated for their reliability in a controlled access test facility near Lewistown, Montana. The two new systems were also installed along real roadsides; the buried cable system was installed along Hwy 160 near Durango, Colorado, and the microwave radio signal break-the-beam system was installed along Hwy 3 near Fort Jones, California. At the test facility near Lewistown, Montana, we used horses, llamas, and sheep as models for wild ungulates.

METHODS

Test-bed location

The RADS test-bed is part of the TRANSCEND cold region rural transportation research facility and is located along a former runway at the Lewistown Airport in central Montana (Fig. 1). The test-bed location experiences a wide range of temperatures, and precipitation ranges include mist, heavy rain, and snow; the topography is flat, and the rocky soil does not sustain much vegetation that may obstruct the signals transmitted or received by the sensors. The test-bed consists of an animal enclosure, the two animal detection systems, and six infrared cameras with continuous recording capabilities (Fig. 2). The distance covered was 50 m (164 ft) for buried cable system and 91 m (300 ft) for the microwave radio signal break-the-beam system (from the left to the right side of the enclosure).

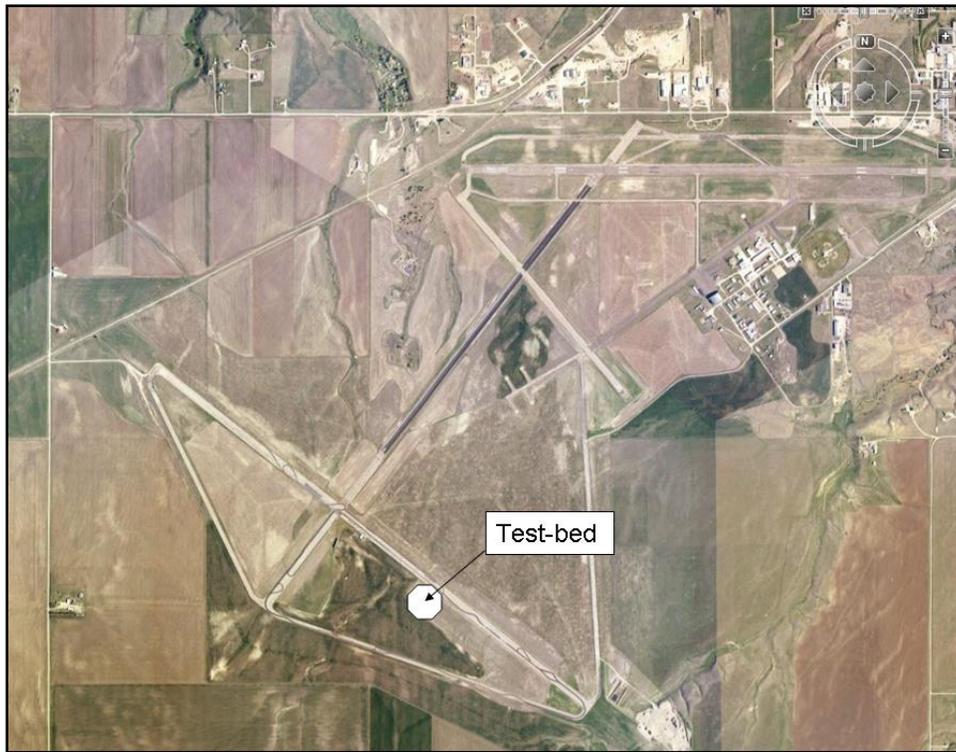


Figure 1. The location of the test-bed along a former runway at the Lewistown Airport in central Montana. The current municipal airport is located on the upper right of the photo.

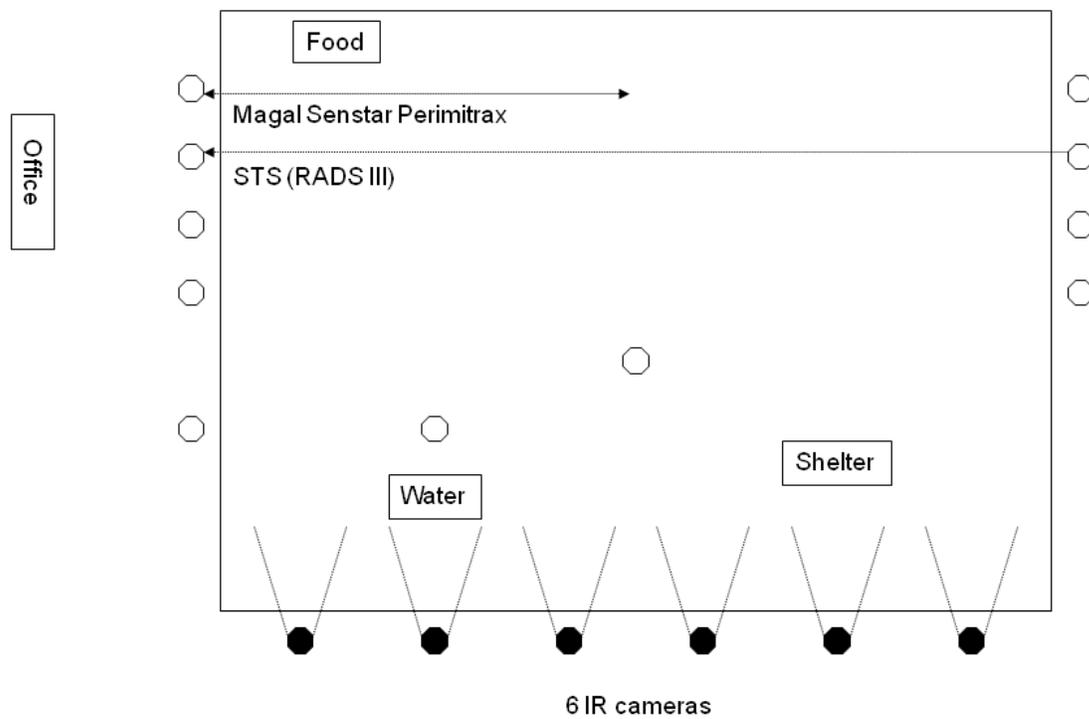


Figure 2. Test-bed design including an animal enclosure, the two detection systems (open circles = poles for sensors), the six infrared cameras aimed at the enclosure from the side (solid circles), and the office with data recording equipment. Arrows show the direction of transmitter.

Animal Detection Systems and Data Recording Equipment

The first system tested is a buried cable (Perimitrax®) that detects large mammals when they move across the cable (Table 1). The system is manufactured by Senstar Corporation, Carp, Ontario, Canada, and it is the exact same technology as originally installed along US Hwy 160 near Durango, CO, USA. The buried cable was placed in a trench and wrapped in sand and geotextile nine inches below the surface. The system was installed in Lewistown on 11 and 12 August 2009. The system generates an invisible electromagnetic field and when a large animal crosses the cable it causes a disturbance in this electromagnetic field. The electrical conductivity, size and speed of the animal all affect the magnitude of the disturbance. However, the threshold that needs to be met to declare an "alarm" or "detection" is adjustable and can be set depending on the size of the animal one wishes to detect. Detection messages are transmitted to a computer in the research trailer at the test-bed where they are saved in files for later analysis.

The second system tested is a microwave radio signal break-the-beam system manufactured by ICx Radar Systems (Scottsdale, Arizona (formerly Sensor Technologies and Systems, Inc.) (Table 1). The system is the third generation of this detection technology (RADS III). Previous generations (RADS I and RADS II) were evaluated for their reliability in an earlier project (Huijser et al. 2009b). The RADS III is the exactly the same detection technology as was installed along Hwy 3 near Fort Jones, CA, USA. The system was installed in Lewistown, MT on 16 December 2009. The center of the beam was set at about 73.7 cm (29 inches) above the ground. However, because of rises and depressions in the terrain, the center of the beam was estimated to have varied between 71.1 and 76.2 cm (28-30 inches) above the ground. Setting the center of the beam lower may have resulted in false positives as a result of the grass-herb vegetation in the enclosure.

**Table 1. The characteristics of the two animal detection systems.
See appendix A for manufacturer contact details.**

Manufacturer and system name	System type	Signal type	Maximum range	Installation date
Magal Senstar (Perimitrax®)	Buried cable	Electromagnetic field	About 0.1 mi (161 m)	11/12 Aug 2009
STS (RADS III)	Break-the-beam	Microwave radio (\pm 35.5 GHz)	About 1/2 mi (804 m)	16 Dec 2009

Six infrared cameras (Fuhrman Diversified, Inc.) were installed perpendicular to the detection system. These cameras and a video recording system record all animal movements within the enclosure continuously, day and night. The two systems saved individual detection data with a date and time stamp in data logs. These data were compared to the images from the infrared cameras, which also had a date and time stamp, allowing the researchers to investigate the reliability of the system. Orange cones marked the location of the cable (first system) and the beam (second system) on the images.

Wildlife Target Species and Models

In a North American setting, animal detection systems are typically designed to detect white-tailed deer (*Odocoileus virginianus*) and/or mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), elk (*Cervus elaphus*) or moose (*Alces alces*). In Montana, it is not legal to have deer, elk or moose in captivity. Therefore the researchers used domesticated species as a model for wildlife. For this study, which took place within an enclosure, two horses, two llamas, and two sheep were used as models for these wildlife target species. Horses are similar in body shape and size to moose, llamas represent deer and elk, and sheep represent small deer (Tables 2 and 3). The body size and weight of the individual horses, llamas, and sheep used in this experiment are shown in Table 4.

Table 2. Height and length of wildlife target species and horses, llamas, goats and sheep.

Species	Height at shoulder	Length (nose to tip tail)	Source
<i>Target species</i>			
Moose	6'5"-7'5" (195-225 cm)	6'9"-9'2" (206-279 cm)	Whitaker (1997)
Elk	4'6"-5' (137-150 cm)	6'8"-9'9" (203-297 cm)	Whitaker (1997)
White-tailed deer	27-45" (68-114 cm)	6'2"-7' (188-213 cm)	Whitaker (1997)
Mule deer	3'-3'5" (90-105 cm)	3'10"-7'6" (116-199 cm)	Whitaker (1997)
Pronghorn	2'11"-3'5" (89-104 cm)	4'1"-4'9" (125-145 cm)	Whitaker (1997)
<i>Models</i>			
Feral horse	4'8"-5' (142-152 cm)		Whitaker (1997)
Quarter horse	4'11"-5'4" (150-163 cm)		UHS (2007), Wikipedia (2007)
Llama	3'-3'11" (91-119 cm)		Llamapaedia (2007)
Goat	25"-30" (64-76 cm)		ADM Alliance Nutrition Inc (2011)
Sheep	25"-50" (63-127 cm)		Minnesota Zoo (2011)

Table 3. Body weight of wildlife target species and horses, llamas, goats and sheep.

Species	Weight male	Weight female	Source
<i>Target species</i>			
Moose	900-1400 lbs (400-635 kg)	700-1100 lbs (315-500 kg)	Whitaker (1997)
Elk	600-1089 lbs (272-494 kg)	450-650 lbs (204-295 kg)	Whitaker (1997)
White-tailed deer	150-310 lbs (68-141 kg)	90-211 lbs (41-96 kg)	Whitaker (1997)
Mule deer	110-475 lbs (50-215 kg)	70-160 lbs (32-73 kg)	Whitaker (1997)
Pronghorn	90-140 lbs (41-64 kg)	75-105 lbs (34-48 kg)	Whitaker (1997)
<i>Models</i>			
Feral horse	795-860 lbs (360-390 kg)	595-750 lbs (270-340 kg)	Whitaker (1997)
Quarter horse	850-1200 lbs (386-540 kg)		UHS (2007), Wikipedia (2007)
Llama	250-450 lbs (113-204 kg)		Llamapaedia (2007)
Goat	110-225 lbs (50-101 kg)	160-264 lbs (72-119 kg)	ADM Alliance Nutrition Inc (2011)
Sheep	100-350 lbs (45-160 kg)	100-225 lbs (45-100 kg)	Wikipedia (2008)

Table 4. Body size and weight of the horses, llamas, and sheep used in the experiment (Pers. com. Lethia Olson, livestock supplier). The measurements were taken in November 2010.

Individual	Height at shoulder	Weight
Horse 1 (Bubba)	5' (152 cm)	1130 lbs (513 kg)
Horse 2 (Buster)	5'2" (157 cm)	1450 lbs (659 kg)
Llama 1 (Sparkle)	3'9" (114 cm)	350 lbs (159 kg)
Llama 2 (Cocoa)	3'9" (114 cm)	470 lbs (213 kg)
Sheep 1	2'4" (71 cm)	170 lbs (77 kg)
Sheep 2	2'5" (74 cm)	225 lbs (101 kg)

Test periods

In 2009 and 2010 there were four ten day test periods with animals:

- Test period 1: Start on November 19, 2009 (at midnight), end on November 28, 2009 (end at midnight).
- Test period 2: Start on December 17, 2009 (at midnight), end on December 26, 2009 (end at midnight).
- Test period 3: Start on July 30, 2010 (at midnight), end on August 8, 2010 (end at midnight).
- Test period 4: Start on September 2, 2010 (at midnight), end on September 11, 2010 (end at midnight).

For each test day (24 hours), the researchers selected three random one-hour-long sections of video for review (stratified random). This resulted in a total of 30 hours during which the reliability of the system was investigated for each test period, and 120 hours for the four test periods combined. The images from the time periods that were analyzed were all saved on DVD. Time periods that were not analyzed were not saved.

In addition, there were two ten day test-periods without domesticated animals present in the enclosure:

- Test period 1: Start on December 7, 2009 (at midnight), end on December 16, 2009 (end at midnight).
- Test period 2: Start on January 5, 2010 (at midnight), end on January 14, 2010 (end at midnight).

The detection data from these two periods were screened for the potential presence of detections (which may indicate false positives), and extreme environmental conditions (based on weather data from a nearby meteorological station). The researchers selected 10 hours from this ten day period for review. These hours were non-randomly selected based on potential suspicious detection patterns (i.e., detections were reported while there are no domesticated animals present), and extreme environmental conditions.

Reliability Parameters

The time periods reviewed were analyzed for valid detections, false positives, false negatives, and intrusions in the detection area. These terms are defined below (see Huijser et al. 2009b for more details).

- *False positives* – A false positive was defined as “when the system reported the presence of an animal, but there was no animal in the detection zone.” Thus, each incident in which a system’s data logger recorded a detection, but there was no animal present in the detection zone of that system, was recorded as a false positive. The date and time were recorded for all false positives.
- *False negatives* – A false negative was defined as “when an animal was present but was not detected by the system.” However, due to animal behavior and the design of some detection systems (i.e., some systems are desensitized by the continuous presence of an animal), there are several ways for a false negative to occur. Therefore, various types of false negatives were distinguished and these were recorded separately.
- *Intrusions in detection area* – An intrusion was defined as “the presence of one or multiple animals in the detection zone.” An intrusion began when one or more animals entered the detection zone and ended when all animals left the detection zone.

We compared the reliability data to the recommended performance requirements that were obtained through interviews with three stakeholder groups (Huijser et al. 2009b).

RESULTS

The percentage of false positives (i.e., a detection is reported by a system but there is no large animal present in the detection zone) was relatively low for both systems (Magal Senstar: 0%; STS: 0.41%). However the percentage of false negatives (i.e., an animal is present in the detection zone but a system failed to detect it) differed substantially (Magal Senstar: 1.9%; STS: 16.8%). The percentage of intrusions (i.e., animal intrusions in the detection area) that were detected also varied substantially (Magal Senstar 99.5%; STS: 88.6%). A comparison of the reliability data to the recommended performance requirements that were obtained through interviews with three stakeholder groups (Huijser et al. 2009b) showed that the Magal Senstar system met the recommended requirements, while the STS system did not (Table 5).

Table 5. The reliability of the two systems in relation to the recommended minimum norms. The percentage of intrusions detected is similar, though not exactly the same as the complement of the percentage of false negatives (see Huijser et al. 2009b).

Manufacturer and system name	Meets false positives (yes/no)	Meets false negatives (yes/no)	Meets intrusions detected (yes/no)	Meets overall recommended norms (yes/no)
Magal Senstar (Perimitrax®)	yes	yes	yes	yes
STS (RADS III)	yes	no	no	no

DISCUSSION AND CONCLUSION

The results of the reliability tests showed that the percentage of false positives was low for both systems. The percentage of false negatives was higher than the recommended minimum norm for the STS system though. The STS system also did not meet the suggested minimum norm for detection intrusions in the detection zone. The Magal Senstar system met all of the recommended performance requirements for reliability. However, experiences with installation, operation and maintenance with this system along Hwy 160 near Durango, Colorado, showed that this system may still have problems with the integration of different system components (Huijser et al. 2011). The robustness of this and other animal detection systems (see e.g. Huijser et al. 2009b) may have to be improved before the systems can be deployed on a large scale.

BIOGRAPHICAL SKETCHES

Marcel Huijser received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management (1992-1995), hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals (1995-1999), and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Centre (1999-2002). Currently Marcel works on wildlife-transportation issues for the Western Transportation Institute at Montana State University (2002-present) and he is a member of the Transportation Research Board (TRB) Committee on Ecology and Transportation.

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Mr. Shaowei Wang was a Research Engineer at WTI through 2010, where he focused on systems and software engineering, data mining and statistical analysis for transportation safety and road weather management, Geographic Information Systems (GIS), software, web, and multimedia development, and cost benefit analysis for engineering applications. He has extensive skills in system architecture design, prototyping, simulation, and modeling. Mr. Wang holds a Master's Degree in Industrial and Management Engineering from Montana State University. He is also a member of the International Council on Systems Engineering.

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