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16. Abstract

This project was initiated in the fall of 1999. The results through the fall of 2005 (Phase I) have been documented in detail in an earlier report. The accomplishments of Phase I included the following: the identification of existing animal detection system technologies and their vendors; the selection of two of these systems for field tests; the deployment of the two selected systems (one in Yellowstone National Park in Montana, and one in Pennsylvania); the documentation of the experiences with system installation; the testing of the reliability of the systems; and formulating advice for the future development and application, including cost-benefit analyses. One of the two experimental animal detection systems (Montana site) proved to be able to detect elk (*Cervus elaphus*) reliably. However, as a result of steep slopes and curves, the system had blind spots where large animals were able to approach the road undetected. Therefore the warning signs could not be attached, and the effectiveness of the system in reducing vehicle speed and in reducing the number of collisions with large wild animals could not be evaluated.

In Phase II of the project, subject of the current report, system modifications reduced the blind spots so that the warning signs could be attached. Speed measurements showed that passenger cars, pick-ups, vans, and trucks with two units or more all had lower vehicle speed with the warning signs activated compared to warning signs off. The number of collisions with large wild animals was 58-67% lower than expected, but because of the variability in the number of collisions and only one year of post installation collision data, the researchers could not test whether this reduction was significant. The opinions on and experiences of drivers with the system were documented in interviews. A majority would have liked to see the US Highway 191 system stay in place (59%), and thought animal detection systems were a good idea, in general (71%). In accordance with an agreement with Yellowstone National Park, the system was removed in fall 2008, due to high maintenance, lack of spare parts and concerns about landscape aesthetics,. Finally, this report includes a recommended step plan for agencies considering the installation of an animal detection system alongside a road and recommendations for future research and monitoring of the reliability and effectiveness of animal detection systems.

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ANIMAL-VEHICLE CRASH MITIGATION USING ADVANCED TECHNOLOGY PHASE II: SYSTEM EFFECTIVENESS AND SYSTEM ACCEPTANCE

Final Report

SPR 3(076)

ANIMAL-VEHICLE CRASH MITIGATION USING ADVANCED TECHNOLOGY
PHASE II: SYSTEM EFFECTIVENESS AND SYSTEM ACCEPTANCE

Final Report
SPR 3(076)

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and

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Washington, D.C. 20590

March 2009

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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Representatives of the DOTs that funded the project, the system vendor, and WTI-MSU personnel during a field visit at the MT site on 15 July 2008 (Photo: Marcel Huijser, WTI-MSU).

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DISCLAIMER

ANIMAL-VEHICLE CRASH MITIGATION USING ADVANCED TECHNOLOGY
PHASE II: SYSTEM EFFECTIVENESS AND SYSTEM ACCEPTANCE

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EXECUTIVE SUMMARY

The Animal-Vehicle Crash Mitigation Using Advanced Technology Study was initiated in the fall of 1999. The results through the fall of 2005 (Phase I) have been documented in detail in an earlier report; the accomplishments of Phase I included the following:

- Identification of existing animal detection system technologies and their vendors;
- Selection of two of these systems for field tests;
- Deployment of the two selected systems (one in Montana, and one in Pennsylvania);
- Documentation of the experiences with system installation;
- Testing of the reliability of the systems; and
- Formulating advice for future development and application, including cost-benefit analyses.

One of the two experimental animal detection systems – the one that was installed along US Highway 191 in Yellowstone National Park, Montana – proved to be able to detect elk (*Cervus elaphus*) reliably. However, as a result of steep slopes and curves, the system had blind spots where large animals were able to approach the road undetected. Therefore the warning signs could not be attached, and the effectiveness of the system in reducing vehicle speed and in reducing the number of collisions with large wild animals could not be evaluated.

Phase II of the project, the subject of the current report, was aimed at making the system modifications required to be able to attach the warning signs and investigate the effectiveness of the system in reducing vehicle speed and in reducing the number of collisions with large wild animals. This summary is structured according to the objectives for Phase II:

Objective 1: Modify the system so that the blind spots cover 2-5% of the total length of the system at the most, install remote access to the system through a satellite connection, and make other repairs and modifications as necessary.

The system was modified and repaired (see Chapter 2). After system modifications, blind spots covered 1.09% of the total length of the system, which meant that better coverage was achieved than the stated objective. Remote access through a satellite connection was achieved, not only allowing for a higher intensity of system monitoring, but also allowing for the warning signs to be manually turned on or off, either for research or management purposes.

System monitoring revealed that various parts of the system showed ongoing wear and tear and that replacement parts were sparse or not available. This led to repairs rather than replacements and relatively intensive monitoring of the system for potential new problems. Mainly because of the experiences at the study site, the vendor (STS, now ICx Radar Systems) has developed a more integrated, more compact, and more robust animal detection system. This should result in a smaller footprint and a reduced impact on landscape aesthetics, more reliable operation (fewer false positives and false negatives), longer life span, and greater distance between the sensors and associated equipment.

Objective 2: Investigate the effectiveness of the system with regard to reduction of vehicle speed in response to activated warning signs.

Southbound traffic reduced speed when traveling through the road section with the animal detection system, both with warning lights off and on. Northbound traffic increased speed when traveling through the road section with the animal detection system, both with warning lights off and on. It is uncertain why northbound traffic increased speed. Perhaps this increase in speed related to the geometry of the road, sight distance, or the proximity of the boundary of Yellowstone National Park two miles farther north.

Nonetheless, passenger cars, pick-ups, vans, and trucks with two units or more all had lower vehicle speed with the warning signs activated compared to warning signs off. For both travel directions combined, the speed of passenger cars, pick-ups, and vans was 1.52 mi/h (2.45 km/h) lower with warning signs activated. For trucks with two units or more vehicle speed was 0.91 mi/h (1.46 km/h) lower with warning signs activated.

While vehicles only reduced their speed by a small degree, reductions in vehicle speed are associated with a disproportionate decrease in the probability of severe accidents when traveling at high speed (*Kloeden, et al. 1997*). In addition, fewer or less severe wildlife-vehicle collisions may not only be obtained through lower vehicle speed, but can also be obtained through increased driver alertness (see Chapter 1, Introduction). 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 sec to 0.7 sec if drivers are warned (*Green 2000*). With a constant passenger vehicle speed of 57.45 mi/h (92.44 km/h) with lights on, this leads to a potential reduction in stopping distance of 67.3 ft (20.5 m).

Objective 3: Investigate the effectiveness of the system with regard to the number of collisions with large animals.

The number of reported collisions with large mammals or the number of large mammal road mortalities from the treatment section after the system became operational was 66.7% lower than before the system became operational. The number of reported collisions with large mammals or the number of large mammal road mortalities from the treatment section after the system became operational was 57.6% lower than in comparable control sections. While both the comparison in time and space suggest that the animal detection system resulted in fewer collisions with large mammals, the relatively short road length of the treatment section combined with one year of data collection after the system became operational do not allow for a statistical test and a firm conclusion. Nonetheless, the available data on the effectiveness of animal detection systems in reducing collisions with large mammals is consistent and suggests that animal detection systems indeed result in fewer collisions with large mammals (see review in Chapter 4). It is important to note though that an animal detection system must be detecting large animals reliably before one investigates the effectiveness of a system in reducing collisions with large mammals.

Objective 4: Investigate the acceptance of the system by drivers, the Montana Department of Transportation, and Yellowstone National Park.

A majority of drivers who responded to the survey and who drove the road section with the animal detection system had the following responses to the survey:

- Often or always worried about hitting large ungulates on the road (81%);
- Noticed the animal detection system (96%);
- Were aware that large animals may be on or near the road in this area when the warning signs were activated (91%);
- Reduced their speed (40%) or became more alert (45%) as a result of the activated warning signs;
- Thought the system was helpful when it was activated (52%);
- Would like to see the US Highway 191 system stay in place (59%);
- Thought animal detection systems were a good idea, in general (71%);
- Expected animal detection systems to detect all (32%) or nearly all (19%) large animals that approach the road;
- Would allow for no more than 20% of all detections to be false (i.e., not related to large animals) (52%);
- Expected animal detection systems to reduce collisions with large animals by over 70% (60%);
- Found it very important to make potential improvements on the reliability of animal detection systems (63%); and
- Found it very important to have clear and easy to understand warning signals (64%).

However, 17% of the respondents thought there were no animals on or close to the road, or did not understand the meaning of the signs when the warning signs were not activated, perhaps leading to an absent or wrong driver response (less alert, faster vehicle speed). The respondents who were critical of the animal detection system along US Highway 191 in Yellowstone National park expressed concerns about the reliability of the system, the costs of this type of mitigation measure, and the effect of the system on landscape aesthetics.

The Montana Department of Transportation (MDT) was concerned about the reliability and robustness of the animal detection system and maintenance effort (see also *Huijser, et al. 2006*). Although the system had proven to detect elk reliably (see also *Huijser, et al. 2006*), the requirements for system coverage were met (see Chapter 2), and remote access through satellite was established to facilitate system monitoring and system management, nevertheless substantial concerns remained with regard to the wear and tear of the system, the associated level of system monitoring, and lack of spare parts. These concerns caused MDT to support system removal after completion of the research project. Yellowstone National Park was mostly concerned about landscape aesthetics (see also *Huijser, et al. 2006*). For Yellowstone National Park, system removal was a condition for Phase II of the project.

Objective 5: Remove the system by 31 August 2008, as a condition set by Yellowstone National Park.

On 18 August 2008 the first sensors were removed. System removal was completed on 12 September 2008.

In addition to addressing the objectives discussed above, the researchers formulated a step plan for agencies considering the installation of an animal detection system alongside a road and recommendations for the research and monitoring of the reliability and effectiveness of animal detection systems.

If a transportation agency is interested in deploying an animal detection system, the following steps are recommended:

- Define the problem;
- Obtain an overview of all effective mitigation measures;
- Obtain an overview of all animal detection systems;
- Select a system;
- Take lessons from other projects into account;
- Prepare for technical difficulties, delays, and maintenance;
- Make a realistic risk assessment;
- Conduct system acceptance tests;
- Document and publish experiences; and
- Document and publish data on system reliability and system effectiveness.

The researchers formulated the following recommendations for the research and monitoring of the reliability and effectiveness of animal detection systems:

- Measure system reliability;
- Standardize how system reliability is measured;
- Investigate the influence of environmental conditions;
- Suggest and adopt minimum norms for system reliability;
- Conduct meta-analyses;
- Consider a BACI analysis;
- Keep the search and reporting effort for crashes and carcasses constant;
- Investigate the mechanism behind system effectiveness;
- Investigate system reliability along the roadside;
- Investigate the effect of the system and activated signs on speed on-site; and
- Investigate the effect of the system and activated signs on driver response on-site.

While animal detection systems should still be characterized as experimental, the results of Phase II of this project are encouraging and suggest that animal detection systems can be effective in reducing collisions with large mammals. Nonetheless, additional research is needed, especially with regard to the effectiveness of animal detection systems in reducing collisions with large mammals, as the current data are not robust.

1.0 INTRODUCTION

1.1 BACKGROUND

The Animal-Vehicle Crash Mitigation Using Advanced Technology Study was initiated in the fall of 1999. The objectives of the project were as follows:

- Identify existing animal detection system technologies and their vendors;
- Select two of these systems for field tests at two sites;
- Document the experiences with installation;
- Test the reliability of the systems;
- Collect post-implementation site data;
- Evaluate the effectiveness of the systems;
- Document system acceptance; and
- Provide advice for future development and application.

The results of this study, from its initiation through the fall of 2005, were documented in detail in the report, Animal Vehicle Crash Mitigation Using Advanced Technology; Phase I: Review, Design, and Implementation (*Huijser, et al. 2006*). One of the two experimental animal detection systems – the one located along US Highway 191 in Yellowstone National Park – proved to be able to detect elk (*Cervus elaphus*) reliably. While some of the objectives listed above had been achieved by the fall of 2005, system modifications were required and additional study was needed to assess the reliability, effectiveness and public acceptance of the system.

Phase II, the subject of this report, focuses on the animal detection system along US Highway 191 in Yellowstone National Park. This report describes the system modifications to address the blind spots, system reliability, system effectiveness, and system acceptance. A basic description of the system and the specific research objectives are provided in the next two sections.

1.2 THE ANIMAL DETECTION SYSTEM ALONG US HIGHWAY 191 IN YELLOWSTONE NATIONAL PARK

In October and November 2002 the animal detection system was installed along a 1 mi (1,609 m) road section of US Highway 191 (mileposts 28-29) in Yellowstone National Park south of Big Sky, Montana (*Huijser, et al. 2006*) (Figure 1.1 and 1.2). The system was designed and integrated by Sensor Technologies and Systems (now ICx Radar Systems).[1] Each transmitter sent a uniquely coded, continuous microwave RF signal (35.5 GHz) to its intended receiver (*Huijser, et al. 2006*). The transmitters and receivers were mounted about 4 ft (120 cm) above the ground, designed to detect elk (*Cervus elaphus*).

[1] ICx Radar Systems, 8900 East Chaparral Road, Scottsdale, AZ 85250

If this signal was blocked or if the signal strength was reduced below a certain threshold, the receiver sent a UHF radio signal to the master station. The master station then sent a "beacon-on" command to the three nearest beacons. There were four beacons in total, two for each travel direction, as shown in Figure 1.2.

Each beacon was situated above warning signs that said "WILDLIFE CROSSING" and "NEXT 1 MILE" or "NEXT ½ MILE" and "WHEN FLASHING." Figure 1.3 shows one of the warning sign assemblies. The flashing beacons were intended to alert oncoming traffic that there may be a large animal on or near the road. After a designated timeout period (3 minutes), the master station transmitted a "beacon-off" command to the beacon stations. If the signal was blocked continuously, the beacons stopped flashing after 12 minutes.

The system recorded every break-of-the-beam, how long the break lasted, the date, the time, and the detection zone number. There were six detection zones on the east side of the road and nine on the west side of the road. The detection data were stored on a MultiMedia Card (MMC) at the master station.

Figure 1.1: Location of the animal detection system on US Highway 191 in Yellowstone National Park, Montana

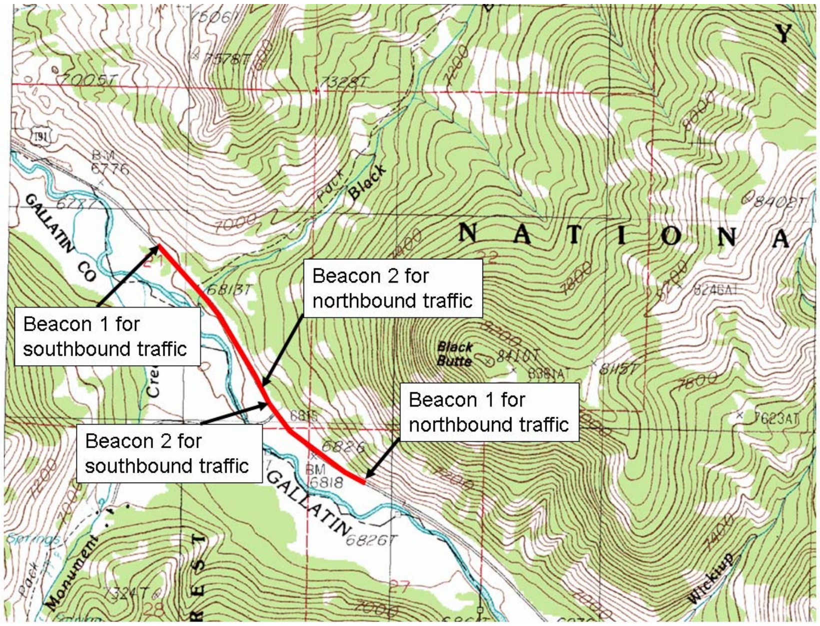

Figure 1.2: Location of the beacons within the 1 mi (1,609 m) animal detection area (shown by red line)

Figure 1.3: Activated warning sign (Beacon 1 for northbound traffic) with flashing beacon on top (Photo: Marcel Huijser, WTI-MSU)

1.3 STUDY OBJECTIVES

Phase II of the Animal-Vehicle Crash Mitigation Using Advanced Technology Study focused on the following objectives:

- Modify the system so that the blind spots cover 2-5% of the total length of the system at the most, install remote access to the system through a satellite connection, and make other repairs and modifications as necessary.
- Conduct further tests on system reliability.
- Investigate the effectiveness of the system with regard to reduction of vehicle speed in response to activated warning signs.
- Investigate the effectiveness of the system with regard to the number of collisions with large animals.
- Investigate the acceptance of the system by drivers, the Montana Department of Transportation, and Yellowstone National Park.
- Remove the system by 31 August 2008, as a condition set by Yellowstone National Park.

1.4 PROJECT FUNDING

This project was funded by the Federal Highway Administration and 15 Departments of Transportation through a pooled fund study (SPR 3(076)). The participating Departments of Transportation were as follows: Alaska Department of Transportation and Public Facilities, and the Departments of Transportation of California, Indiana, Iowa, Kansas, Maryland, Montana, Nevada, New Hampshire, New York, North Dakota, Oregon, Pennsylvania, Wisconsin, and Wyoming.

Oregon Department of Transportation (ODOT) administered the project funds from the individual states (totaling $1,125,000) and managed the contract with the Western Transportation Institute at Montana State University (WTI-MSU). Additional funds ($255,676) came from WTI-MSU (University Transportation Center funds) to help cover the installation, project extension costs, and part of Phase II at the Montana study site. This brought the total project budget up to $1,380,676 (Phases I and II combined). Figure 1.4 shows the financial contributions from each state and WTI-MSU.

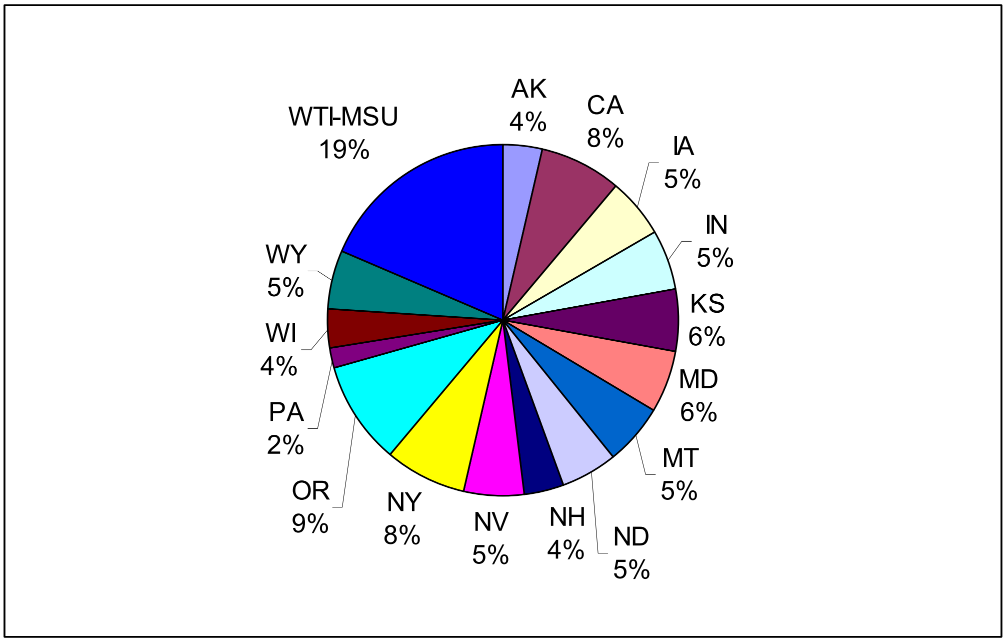

Figure 1.4: Financial contributions to the research project (Total: $ 1,380,676)

Over and above the project budget, the Pennsylvania Department of Transportation (PennDOT) estimated that an additional $130,000 was spent by PennDOT on coordination, engineering plans, installation, and efforts to help identify and address problems after installation for the Pennsylvania study site during Phase I.2 In addition, the Oregon Department of Transportation spent additional funds on coordination, administration, and report editing and publication. The Montana Department of Transportation (MDT) spent an unknown amount of funds on coordination, support for installation, efforts to help identify and address problems after installation, and system removal for the Montana study site. These contributions of PennDOT , ODOT, and MDT were not part of the funds administered by ODOT or WTI-MSU and were excluded from Figure 1.1.

[2] Dennis Prestash, PennDOT, personal communication, 18 November 2004. Also see *Huijser, et al. 2006*.

2.0 SYSTEM MODIFICATIONS

2.1 PROBLEMS ENCOUNTERED THROUGH 2005

A range of problems was encountered from the time the system was implemented through 2005, when the second phase of the study started. The system was found to have blind spots where large animals such as elk were able to approach the road undetected. These blind spots were caused be steep slopes and curves. Because of the blind spots, the warning signs could not be installed, as that would have given drivers the false expectation that large animals would be detected by the system throughout the test section. In addition, the brackets that hold the sensors were found to be sensitive to breaking due to the temperature fluctuations at the location. Furthermore, the radio link between one of the receiver stations and the master station was not always successful, either because of a lack of a line of sight, or because of a software issue in the radio of the receiver station. Finally, although limited remote access was established to the system through the land-based phone line, it was considered too unreliable.

The problems described above had to be addressed before the warning lights could be plugged in and the warning signs attached. Only then would the Western Transportation Institute at Montana State University (WTI-MSU) be able to investigate the effectiveness of the animal detection system and system acceptance.

2.2 SITE SURVEY

A detailed survey was conducted by the vendor to confirm the presence and exact location of the blind spots (see also *Huijser, et al. 2006*). The vendor then provided suggestions and budget estimates on how to address these blind spots.

Figure 2.1 shows a schematic layout of the system until the autumn of 2006. Figure 2.2 shows the estimated length of the blind spots, ordered by length. The total length of the blind spots was estimated at about 1,115 ft (340 m), which was 10.6% of the 2*1 mi (2*1,609 m) road section covered by the system.

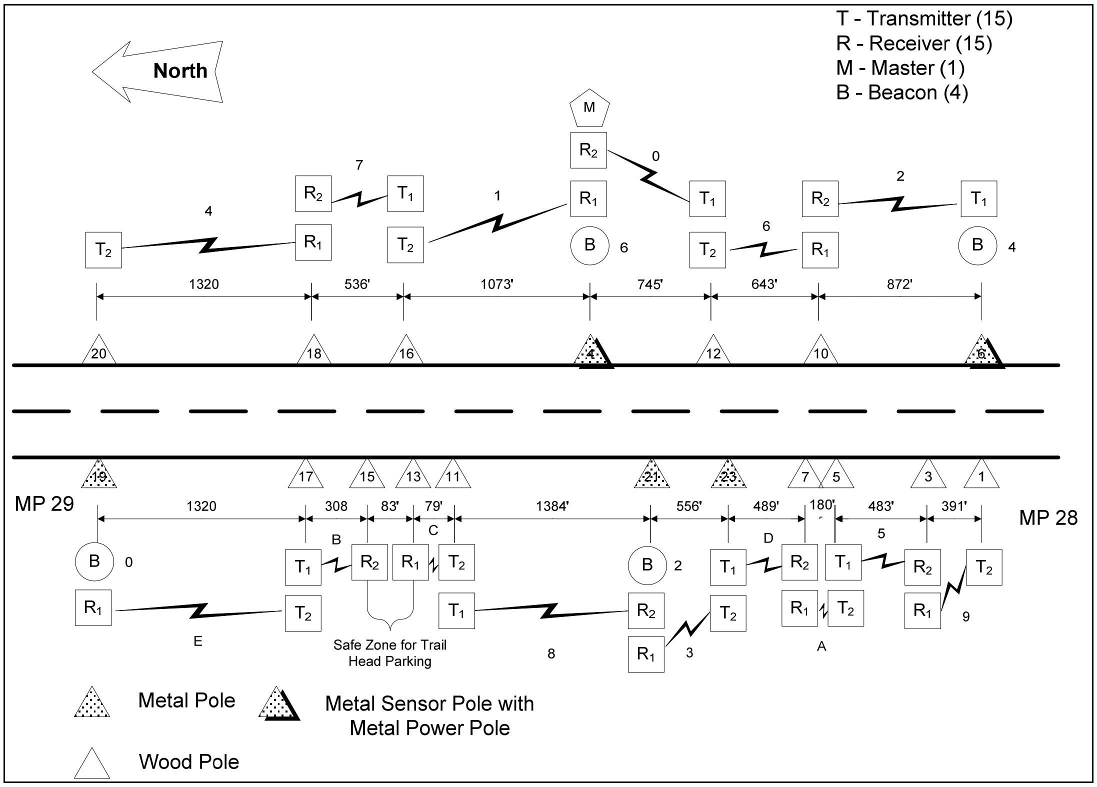

Figure 2.1: Schematic layout of the system autumn 2002 – autumn 2006. The detection zones are indicated by a number or by a capital letter at each "lightning" symbol.

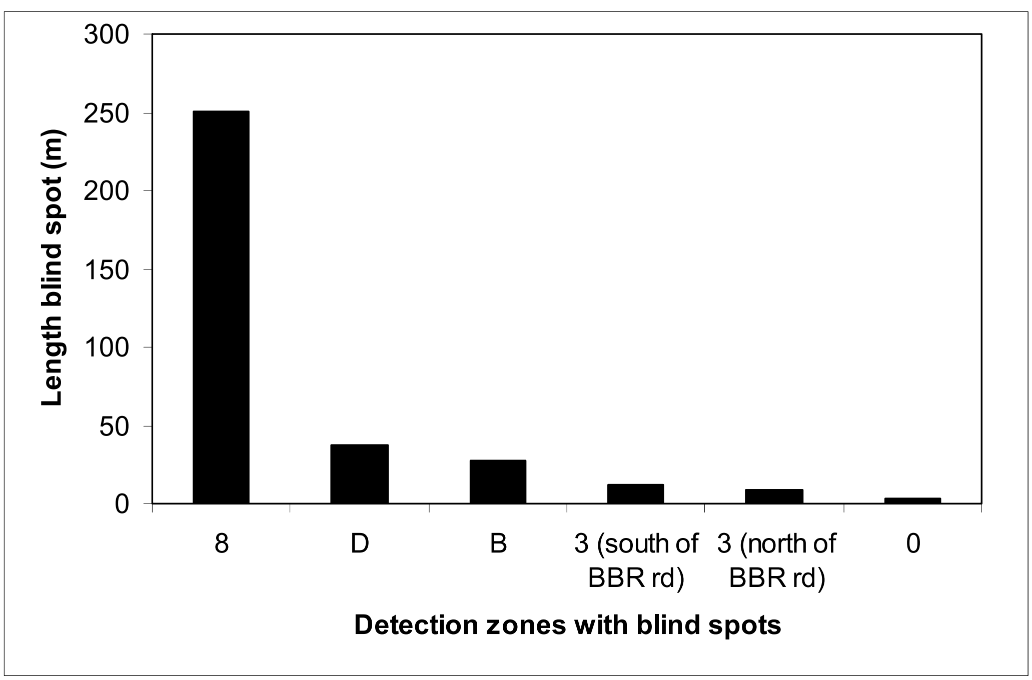

Figure 2.2: Length of the individual blind spots (BBR rd = Black Butte Ranch access road)

The estimated costs to address the blind spots are shown in Figure 2.3. The costs are given per m of the blind spot. Based on these calculations, the zone D blind spots were recommended to be corrected first and zone 3 (south and north of the Black Butte Ranch access road) last.

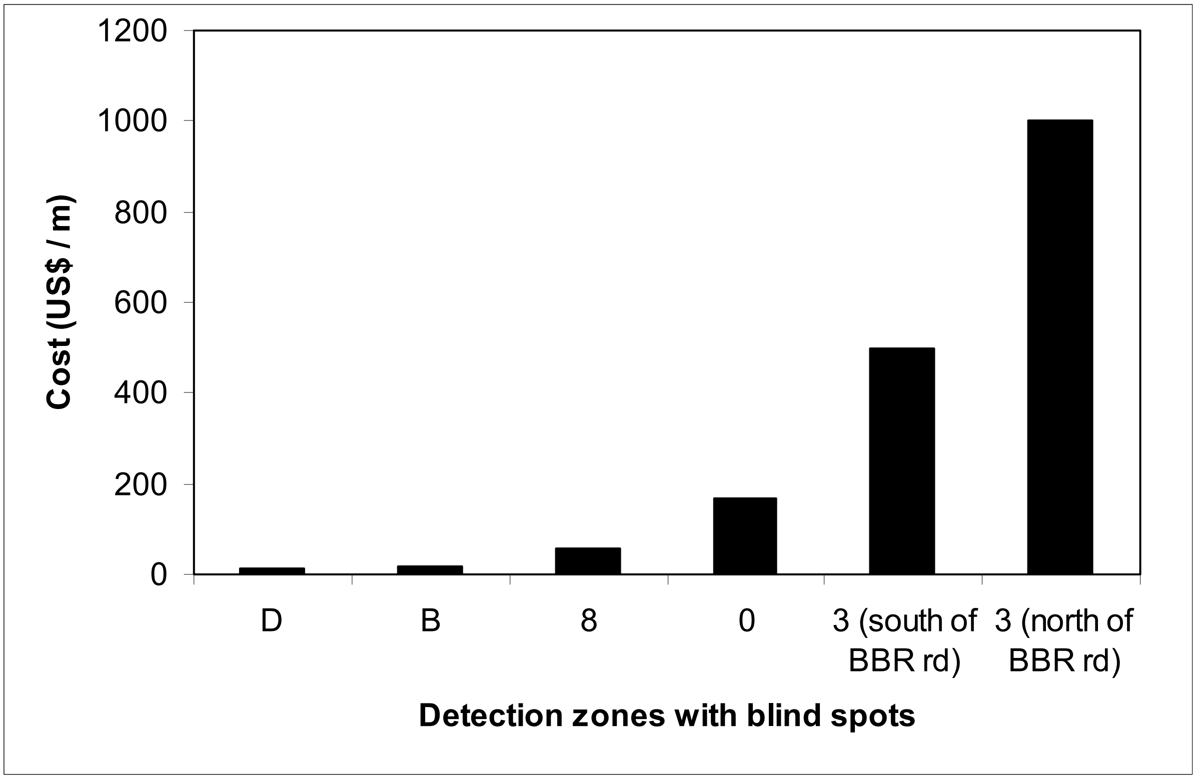

Figure 2.3: Costs to address the individual blind spots (BBR rd = Black Butte Ranch access road)

Figure 2.4 shows the estimated reduction in the percentage of blind spots in the total 2*1 mile-length covered by the system (2*1,609 m), given the correction of individual blind spots in the given order. WTI-MSU proposed a cut-off level for the blind spot correction. This resulted in accepting the blind spots in Detection Zone 3 (north and south of the Black Butte Ranch access road). The total length of these two blind spots was estimated at 71.2 ft (21.7 m), which was 0.7% of the road section covered by the system.

The proposed system modifications included removing Station 13, relocating Station 11 (Figure 2.5), and including the entrance to the parking area for the Black Butte Trailhead in the sensor array. The Technical Advisory Committee (TAC) for the project had decided that, after system modifications, the percentage of blind spots in the total length of the system must be between 2% and 5% at a maximum. Should a higher percentage of the system have blind spots after system modification, the system would have to be removed.

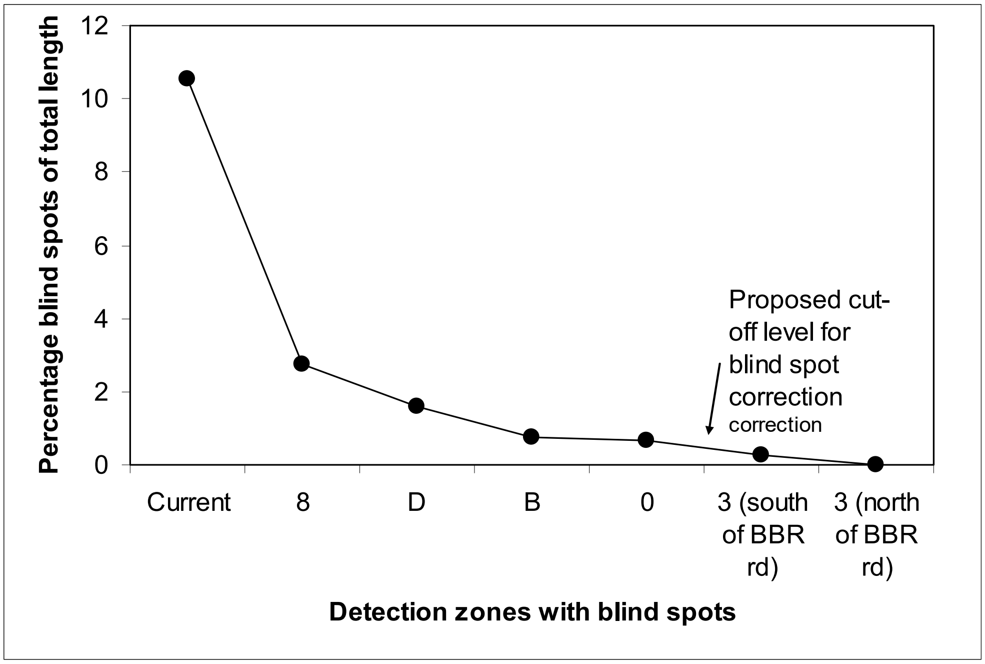

Figure 2.4: Proposed order and cut-off level for blind spot corrections (BBR rd = Black Butte Ranch access road)

Figure 2.5: Proposed relocation of Station 11, looking south; relocated 275 ft (84 m) to the southeast (at a bend in the road, indicated by arrow) (Photo: Lloyd Salsman, STS)

The site survey showed that the master station did not have to be relocated. New software was effective in reducing the radio errors from the most southern stations. The site survey showed, however, that some hardware was broken, including a damaged master board (logging memory and real time clock) as a result of battery vapors. In addition, several diodes were producing high noise levels (specifically ST04, ST13, ST21, and ST19). Sensors, several solar panels, and other hardware also needed to be reinstalled. Several beam tubes needed to be re-aligned; sensors needed to be lowered on the poles; and system functioning needed to be verified. Remote access through a satellite connection was also recommended.

Vegetation trimming was needed between some of the sensors, as the vegetation had grown into the beam since system installation. Vegetation growth and re-growth in some of the sensor paths had caused higher noise levels in the signal. This condition desensitized the beam and led to missed detections. The area that was most sensitive to vegetation obstructing the signal was the first 15 ft (4.6 m) in front of each sensor. This finding implies that, at a minimum, the grass-herb vegetation needs to be kept short in the areas immediately in front of the sensors. In some cases (re)growth of shrubs and trees blocked the beam farther away from the sensors. The proposed vegetation management practices were similar to the ones conducted in the past under supervision of a representative of Yellowstone National Park.

2.3 MODIFICATIONS TO SYSTEM

The TAC adopted the proposed strategy and cut-off levels to address the blind spots. Figure 2.6 shows a schematic layout of the system after the blind spot corrections took place. Figures 2.7-2.9 show the removal of Station 13 and the relocation of Station 11.

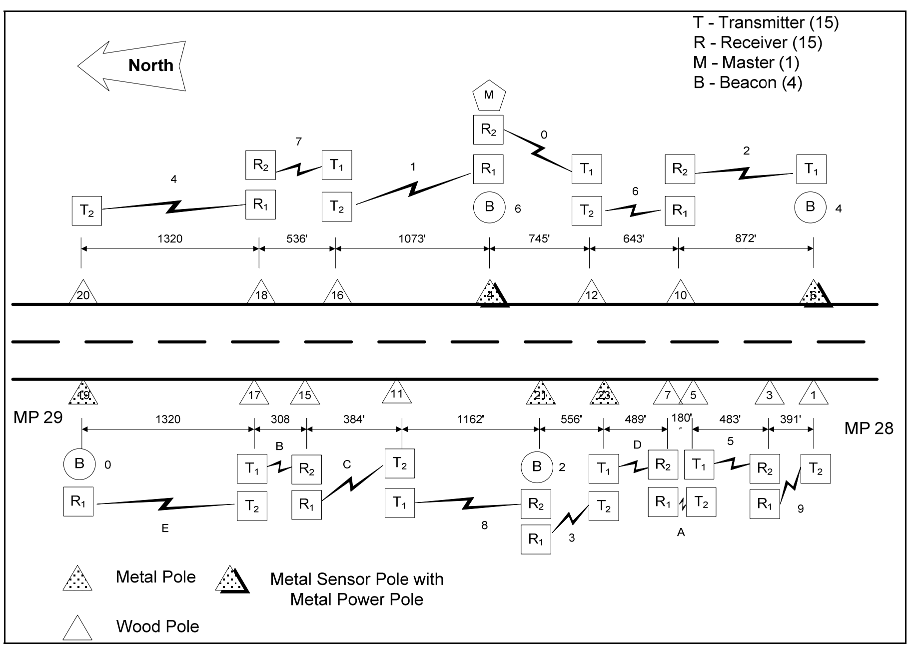

Figure 2.6: Schematic layout of the system autumn 2006 – August 2008. The detection zones are indicated by a number or by a capital letter at each "lightning" symbol.

Figure 2.7: Area just south of Black Butte Trailhead after Station 13 was removed and Station 11 was relocated. Station 11 (new location) can be seen on the left side of the tree (Photo: Marcel Huijser, WTI-MSU).

Figure 2.8: Station 11 at its new location, looking north (Detection Zone C) towards Station 15 and Black Butte Trail parking area (Photo: Marcel Huijser, WTI-MSU)

Figure 2.9: Station 11 at its new location, looking south (Detection Zone 8) towards Station 21 and Black Butte Ranch access road (Photo: Marcel Huijser, WTI-MSU)

Table 2.1 shows a list of all system modifications. Figures 2.10 and 2.11 show a selection of these system modifications.

Table 2.1: List of system modifications accomplished

Item
Remove ST 11 and ST 13 (see Figures 2.1 and 2.6 for reference)
Transfer surplus equipment to MDT
Install new pole and equipment (ST 11 in Figure 2.6)
Conserve topsoil and vegetation during system modifications
Paint new station (ST 11 in Figure 2.6)
Install new break-away pole (ST 11 in Figure 2.6)
Manage vegetation (mow and cut vegetation growing in beam paths)
Repair master board
Replace brackets that hold all sensors
Reduce Radio error for communications between receiver stations and the master station
Establish remote access to the master station through a satellite connection

Figure 2.10: Sensor equipped with new bracket (aluminum casting, metal bands around sensor tube) (Photo: Marcel Huijser, WTI-MSU)

Figure 2.11: Antenna for remote access through satellite connection (Photo: Marcel Huijser, WTI-MSU)

2.4 VERIFICATION OF MODIFICATIONS TO SYSTEM

After system modification, testing for blind spots was done by using a human (height 5 ft 6 in (1.68 m)) as a model for large ungulates. The human model crossed each detection zone at approximately 30 ft (9.1 m) intervals. The exact location was verified before each crossing of the beam with a laser range finder. System coverage was verified by visually observing blockage of the sensor on the other side of the human model as well as by measuring the signal strength and verifying that the thresholds for detection were met at the receiver of the individual detection zones.

The testing revealed that there were no blind spots present, except in Detection Zone 3 (55 ft (≈16.9 m), and Detection Zone D (60 ft (≈18.3 m)). The blind spots in Detection Zone 3 were related to a sensor that had to be placed high on a pole in order to shoot the beam across the Black Butte Ranch access road. The blind spot in Detection Zone D resulted from the sensor at Station 23 shooting up a slope towards Station 7. Figures 2.12 – 2.14 show these blind spots from various perspectives. The total length of the blind spots after system modifications was estimated at 115 ft (35.2 m), or 1.09% of the total length covered by the system. This number was well below the maximum percentage of allowable blind spots (5%).

Figure 2.12: Looking north from Station 23 (Detection Zone 3) towards the Black Butte Ranch access road and Station 21. There is a blind spot in the area between Station 23 and the Black Butte access road because the sensor had to be placed high on the pole in order to shoot across the embankment of the Black Butte access road (Photo: Marcel Huijser, WTI-MSU).

Figure 2.13: Looking south from the Black Butte Ranch access road towards Station 23. There is a blind spot in the area between the Black Butte access road and Station 23; the same blind spot is illustrated in Figure 2.12 (Photo: Marcel Huijser, WTI-MSU).

Figure 2.14: Looking north from the Black Butte Ranch access road towards Station 21. There is a blind spot in the area between the Black Butte access road and Station 21, because the sensor on Station 23 had to be placed high on the pole in order to shoot across the embankment of the Black Butte access road (see Figure 2.12) (Photo: Marcel Huijser, WTI-MSU).

System operation was further verified through analyzing the detection log of the system. The remote access through the satellite was verified by issuing commands through the interface (http://www.vikoninternational.com/), which was accessible from any computer with internet access, the required login name and password. Figures 2.15 and 2.16 show the remote access interface.

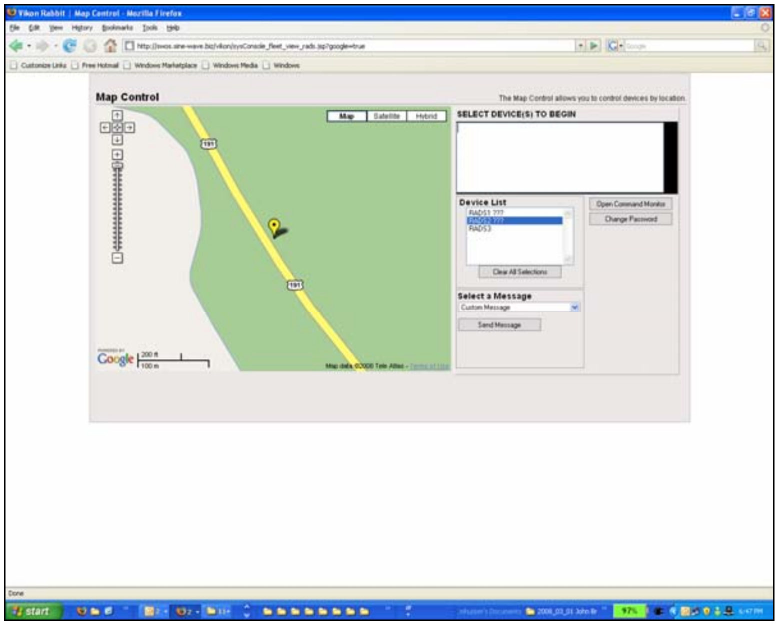

Figure 2.15: Remote access interface: this screen allows for system selection and issuing commands through the satellite to the system.

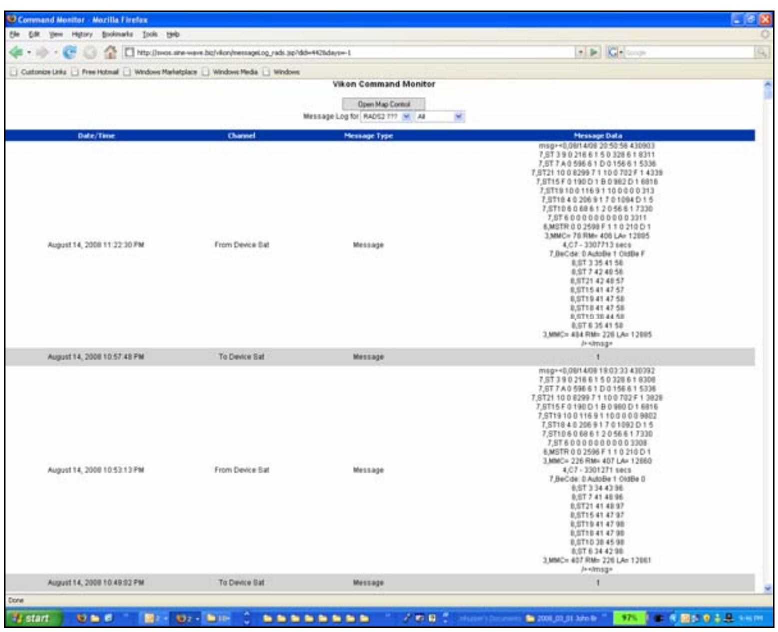

Figure 2.16: Remote access interface: this screen shows the command and response log for messages to and from the system.

2.5 OPERATION AND MAINTENANCE 2007-2008

The beacons were plugged in and the warning signs were attached on 18 January 2007. The system remained in operation through 18 August 2008, when the first sensors were removed as part of the system removal procedure. System removal was completed on 12 September 2008. The holes resulting from the removed foundations and poles were filled with subsoil (from at least six inches deep). The upper two inches of the holes (compared to the surrounding grade) were filled with topsoil, and brush and grass were gently raked from the immediate surroundings of the individual holes. The activities related to subsoil, topsoil, and vegetation were based on the guidance provided by employees of Yellowstone National Park.

The most significant problem encountered during the operation of the system was that various parts of the system showed wear and tear and that replacement parts were sparse or not available. This situation necessitated repairs rather than replacements, and it required relatively intensive monitoring of the system for potential new problems. The Montana Department of Transportation, the vendor (Sensor Technologies and Systems, now ICx Radar Systems), and WTI-MSU worked together on identifying and addressing issues with operation and maintenance through Phase II of the project. Mainly because of the experiences at the study site, the vendor has developed a more integrated, more compact, and more robust animal detection system over the last couple of years. This should result in a smaller footprint (landscape aesthetics), more reliable operation (fewer false positives and false negatives), and greater distance between the sensors and associated equipment (see also *Huijser, et al. 2006*).

2.6 REQUIREMENTS FOR SYSTEM REMOVAL

The Montana Department of Transportation (MDT) was concerned about the reliability and robustness of the animal detection system and maintenance effort (see also *Huijser, et al. 2006*). The requirements for system coverage were met, the system proved to detect elk reliably (see also *Huijser, et al. 2006*), and remote access through satellite was established to facilitate system monitoring and system management. However, substantial concerns remained with regard to the wear and tear of the system, the associated level of system monitoring required, and the lack of spare parts. These concerns caused MDT to support system removal after completion of the research project.

Yellowstone National Park was mostly concerned about landscape aesthetics (see also *Huijser, et al. 2006*). For Yellowstone National Park, system removal after the study was a condition for approval of Phase II of the project.

3.0 SYSTEM EFFECTIVENESS: VEHICLE SPEED

3.1 INTRODUCTION

Once an animal detection system reliably detects the target species, and the warning signals and signs are activated, driver response determines how effective the system ultimately is in reducing animal-vehicle collisions. Figure 3.1 splits driver response into two components: increased driver alertness and lower vehicle speed.

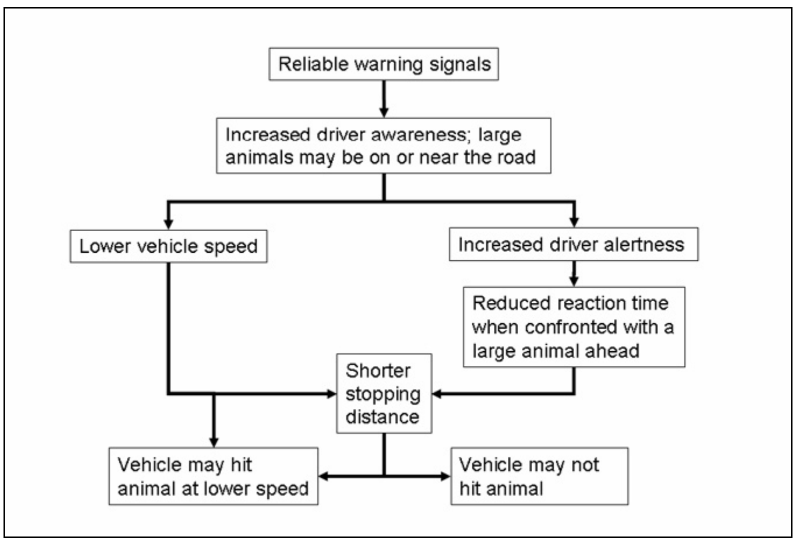

Figure 3.1: Driver response components dependent on reliable warning signals

A higher state of alertness of the driver, lower vehicle speed, or a combination of the two can result in a reduced risk of a collision with the large animal and less severe collisions. A reduced collision risk and less severe collisions mean fewer human deaths and injuries and lower property damage. In addition, fewer large animals are killed or injured on the road without having been restricted in their movements across the landscape. Furthermore, fewer large dead animals will have to be removed, transported, and disposed of by road maintenance crews.

This chapter focuses on the effect of activated warning sings on vehicle speed. Previous studies have shown variable results:

- Substantial decreases in vehicle speed (≥3.1 mi/h (≥5 km/h)) (*Kistler 1998*; *Muurinen and Ristola 1999*; *Kinley, et al. 2003*; *Dodd and Gagnon 2008*);

- Minor decreases in vehicle speed (<3.1 mi/h (<5 km/h)) (*Kistler 1998*; *Muurinen and Ristola 1999*; *Gordon and Anderson 2002*; *Kinley, et al. 2003*; *Gordon, et al. 2004*; *Hammond and Wade 2004*); and

- No decrease or even an increase in vehicle speed (*Muurinen and Ristola 1999*; *Hammond and Wade 2004*).

This variability in results is likely related to various conditions (see also *Huijser, et al. 2006*):

- 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 driver actually sees an animal;

- Whether the driver is a local resident;

- Possibly 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); and

- Possibly cultural differences that may cause drivers to respond differently to warning signals in different regions.

Kistler (*1998*) found that drivers reduced their speeds substantially when presented with activated warning signals that were accompanied with a reduction of the maximum speed limit (24.8 mi/h (40 km/h)). The average vehicle speed decreased from 42.3 mi/h (68 km/h) (warning lights off) to 28.6 mi/h (46 km/h) (warning lights on). Other locations that had warning signs only and no reduced maximum speed limit showed only a minor reduction in vehicle speed. There the average vehicle decreased from 31.7 mi/h (51 km/h) (warning lights off) to 29.2 mi/h (47 km/h) (warning lights on). In this case, however, the average vehicle speed with the warning lights off was relatively low already, and vehicle speed with the lights on was similar to that with activated warning signals in combination with a mandatory reduction in speed limit.

Dodd and Gagnon (*2008*) also found that drivers reduced their speeds substantially when presented with activated warning signals. The average vehicle speed decreased from 62.7 mi/h (100.9 km/h) (warning lights off) to 50.7 mi/h (81.6 km/h) (warning lights on).

During the day, Muurinen and Ristola (*1999*) observed a slight increase in vehicle speed as a response to the activated warning signals: an increase of 0.2-0.3 mi/h (0.4-0.5 km/h). During the night however, there was a minor reduction in vehicle speed: 1.0-1.6 mi/h (1.6-2.6 km/h). Drivers reduced their speeds substantially when it rained, 8.7-9.7 mi/h (14.0-15.6 km/h). These results suggest that drivers are more likely to reduce vehicle speeds and reduce them substantially when visibility and road conditions are poor.

Drivers who live in the area surrounding an animal detection system are more likely to be familiar with the purpose and reliability of an animal detection system than non-locals. If the animal detection system is reliable and if drivers receive confirmation (i.e., observe an animal when warning lights are on and do not when warning lights are off), local drivers may learn to trust an animal detection system. Therefore, local drivers may be more alert, and they may reduce their speed more than non-local drivers. However, if an animal detection system is not reliable, or if the drivers do not receive confirmation, local drivers may be less responsive than non-local drivers.

Kistler (1998) found that local drivers showed greater speed reduction and drove slower than non-locals when warning lights were on (compared to when they were off), as shown in Table 3.1. These findings suggest that local drivers may have trusted the animal detection systems more than non-local drivers. This also suggests that overall driver response may be less pronounced on roads that have a relatively high proportion of non-local drivers. Finally, the results indicate that one is more likely to observe a response to the flashing warning lights (lower vehicle speed) if drivers have been given the opportunity to learn to trust the system. Therefore speed readings taken immediately after system installation may show smaller speed reductions than speed readings taken after a period of time has passed, e.g., three months later.

Table 3.1: Speed reduction comparisons – local vs. non-local drivers

	Local Drivers		Non-Local Drivers	
	Warning Lights Off	**Warning Lights On**	**Warning Lights Off**	**Warning Lights On**
With mandatory speed limit reduction	42.3 mi/h (68 km/h)	27.3 mi/h (44 km/h)	43.5 mi/h (70 km/h)	31.7 mi/h (51 km/h)
Without mandatory speed limit reduction	31.7 mi/h (51 km/h)	27.3 mi/h (44 km/h)	31.1 mi/h (50 km/h)	29.2 mi/h (47 km/h)

Source: *Kistler 1998*

Minor reductions in vehicle speeds may not seem meaningful, but the relationship between vehicle speed and the risk of fatal accidents (for humans) is exponential (*Kloeden, et al. 1997*). This means that at a high vehicle speed a small decrease in speed results in a disproportionately large decrease in the risk of the severity of a potential accident. Thus a relatively small reduction in vehicle speed can be very important. However, the relationship between vehicle speed and the risk of fatal accidents has not specifically been tested with respect to large animals in rural areas.

In this chapter the authors report on their investigation of the effect of activated warning signs on vehicle speeds for the animal detection system along US Highway 191 in Yellowstone National Park, Montana. The researchers expected lower vehicle speed with activated warning signs.

3.2 MATERIAL AND METHODS

3.2.1 Study area and animal detection system

The study area, the animal detection system, and the warning signs are described in Chapter 1. The posted maximum speed limit on US Highway 191 inside Yellowstone National Park was 55 mi/h (88.50 km/h). The northern edge of the road section with the animal detection system was exactly 2 mi south of the boundary of Yellowstone National Park. The posted maximum speed limit north of the Park boundary was 60 mi/h (96.54 km/h).

3.2.2 General study design

All the beacons were forced on at certain times by issuing a command through a web-based interface and satellite connection with the master station (see also Chapter 2). After a certain time, a command was issued to the master station to resume normal operation and stop the continuous flashing of the lights. The detection log saved by the system was used to verify the exact times the lights were forced on and were put back into normal operation again. This capability to manually control the beacons allowed the researchers to select dates and times that all four lights were on continuously. The detection log saved by the system also indicated time periods when none of the beacons was activated. For the study of driver response to the warning signs the researchers selected time periods that were at least 30 min long.

The researchers also installed three traffic counters (see section 3.2.3); one was located outside of the detection area at each end of the 1 mi (1,609 m) long detection area; and one was located at the master station, at about the mid-point of the detection area (Figures 3.2 and 3.3). The traffic counters recorded traffic parameters with a date and time stamp, allowing the researchers to link these measurements to time periods when the beacons were either all on or all off.

Traffic parameters were collected between 13 June and 25 July 2008. Data from this time period were used to investigate the effect of activated warning signs on potential changes in vehicle speeds as traffic approached and traveled through the animal detection area. Data collected at the counter location at the mid-point of the animal detection system (Traffic counter ADS) were also used to investigate the effect of the activated warning signs on vehicle speed. During the data collection period there was mostly no precipitation and the pavement was dry and not slippery. There was no construction in the immediate vicinity of the test area.

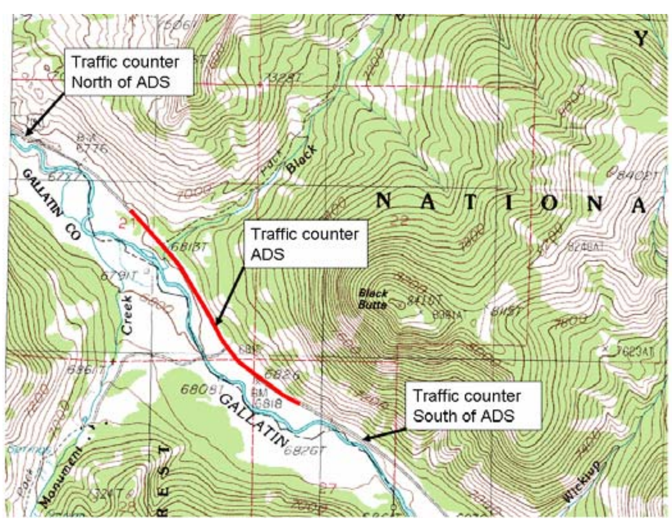

Figure 3.2: Location of the three traffic counters relative to the animal detection area, shown by the red line (see also Figure 2.6). ADS = animal detection system.

Figure 3.3: Tubes of the traffic counter at the master station within the animal detection area (Photo: Marcel Huijser, WTI-MSU)

3.2.3 Traffic counters

JAMAR TraxPro counters and pneumatic road tubes were installed at three locations (Figure 3.2). The counters recorded the date, time, vehicle type, vehicle speed, and gap (in seconds) between vehicles. The vehicle type classifications may be found in Appendix B. The northernmost counter was located approximately 2,461 ft (750 m) from the northern end of the road section with the animal detection system, and the southernmost counter was located approximately 1,722 ft (525 m) from the southern end of the animal detection area. These locations were far enough away from the first beacons for each travel direction (shown in Figure 3.2), so that drivers would not to be able to interpret these warning signs and potentially change their speed in response to them. The counter within the animal detection area was located at or close to the second beacons and warning signs for each travel direction (see Figure 3.2). Thus the data recorded at the traffic counter within the animal detection area recorded traffic parameters from drivers who had passed two beacons and the associated warning signs.

For data analyses the vehicle type categories (Appendix B) were grouped as shown in Table 3.2.

Table 3.2: Grouping of vehicle type categories

Vehicle type groups	Vehicle type classes (Appendix B)
Motorcycles	1
Passenger cars, pick-ups and vans	2 and 3
Buses	4
Trucks (single unit)	5, 6, and 7
Trucks (two or more units)	8, 9, 10, 11, 12, and 13

3.2.4 Minimum gap between vehicles

Depending on the road conditions and traffic volume, vehicles may travel in groups (platoons), as there may be few opportunities to overtake other vehicles. When measuring the effect of the activated warning signs on vehicle speed, it is important to only include the speed data from the first vehicle in a platoon, as the speeds of the following vehicles are likely to be influenced by that of the first vehicle. Except for the speed of the first vehicle, speeds of vehicles that traveled less than 10 seconds apart were discarded.

3.2.5 Sample size and road and weather conditions

Since small reductions in vehicle speed are important, speed studies must have relatively large sample sizes. Figure 3.4 shows the relationship between the required sample size and the detectable speed reduction. For example, in order to detect a substantial reduction in vehicle speed (≥3.1 mi/h (≥5 km/h)), a minimum of 115 vehicles per treatment is required.[3] To detect smaller reductions in vehicle speed a much larger sample size is required. For example, in order to detect a reduction in vehicle speed of ≥1.6 mi/h (≥2.5 km/h), a minimum of 455 vehicles per treatment is required.[4] These numbers are based on a power analysis conducted with speed data from the test site along Highway 191 in Yellowstone National Park (see *Huijser, et al. 2006* for further details). Other sites may have different vehicle speeds and variation in speed; thus other sites may require a higher or lower minimum sample size. For this study the researchers aimed to measure differences in vehicle speed ≥1.6 mi/h (≥2.5 km/h), which required a sample size of at least 455 vehicle speed measurements per treatment.

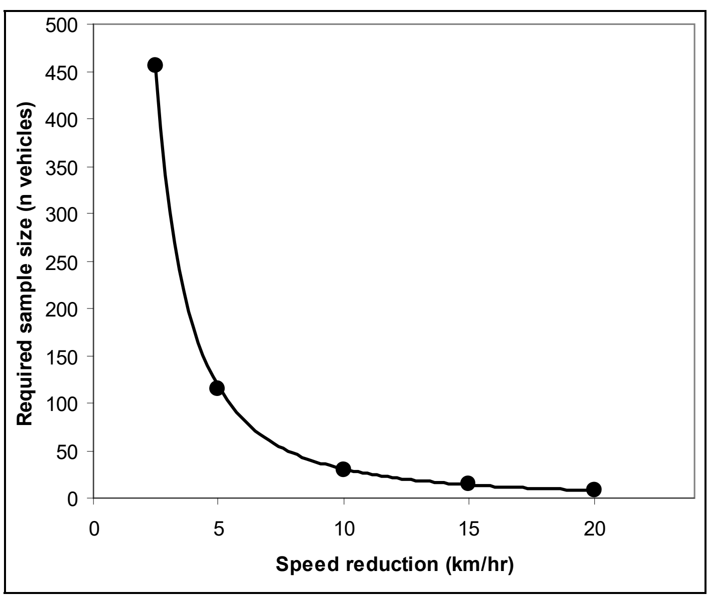

Figure 3.4: Sample size required to detect speed reduction

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[3] 1-sided t-test, $\alpha = 0.05$, power = 0.8
[4] 1-sided t-test, $\alpha = 0.05$, power = 0.8

3.2.6 Driver familiarity with area and system

The researchers recorded the issuing state of vehicle license plates on 16, 17, and 23 June 2008 and on 7, 9, and 17 July 2008. For vehicles originating from Montana, the county number was noted as well. Vehicles with a Montana license plate from Gallatin County and vehicles from Yellowstone National Park were classified as "local traffic." All other vehicles were labeled as "non-local traffic."

3.2.7 Statistical analyses

3.2.7.1 Changes in vehicle speed

Data from all three counters were used to investigate how vehicle speed may change as vehicles approach, travel through, and leave the road section with the animal detection system.[5] These analyses were only carried out for the most abundant vehicle type group: passenger cars, pick-ups and vans. Since vehicle speed follows a Poisson distribution, the natural logarithm (Ln(speed)) was calculated from the variable "vehicle speed."

Separate ANOVA analyses were conducted for northbound traffic and southbound traffic, with Ln(speed) as the dependent variable and with traffic counter location (north of ADS, ADS, south of ADS), visibility (day, night) and warning sign status (lights off, lights on) as explanatory variables, including all interactions. Only interaction and main effects with P-values ≤ 0.05 are discussed below. The mean vehicle speed for each set of conditions was calculated by calculating the mean of Ln(speed) and transforming it back to its original scale in miles per hour.

3.2.7.2 Vehicle speed

Data from the counter inside the animal detection area (Traffic counter ADS) were used to investigate the effect of activated warning signs on vehicle speed in the road section with the animal detection system.[6] Vehicle type groups with less than 250 vehicles per travel direction for daylight conditions were excluded from the analyses (i.e., Motorcycles, Buses, and Trucks (single unit)). Since vehicle speed follows a Poisson distribution, the natural logarithm (Ln(speed)) was calculated from the variable "vehicle speed."

Separate ANOVA analyses were conducted for the two remaining vehicle type groups (Passenger cars, pick-ups and vans, and Truck (two or more units)). These analyses were conducted for each travel direction (northbound, southbound), with Ln(speed) as the dependent variable and visibility (day, night) and warning sign status (lights off, lights on) as explanatory variables, including the interaction of these variables. Only interaction and main effects with P-values ≤ 0.05 are discussed below. The mean vehicle speed for each set of conditions was calculated by calculating the mean of Ln(speed) and transforming it back to its original scale in miles per hour.

[5] Data collection during the period 16 June 2008 through 27 June 2008
[6] Data collection 16 - 27 June 2008, 2 July 2008, 7 - 15 July 2008, and 19 - 25 July 2008

3.3 RESULTS

3.3.1 Traffic characteristics

Average traffic volume (both travel directions combined) was 2,428 vehicles per 24-hour period between noon on 13 June 2008 and noon on 27 June 2008. Traffic volume was similar for southbound (48.9%) and northbound (51.1%) traffic. Figure 3.5 shows the traffic volumes for each hour of the day. Traffic volumes were highest between 10 am and 7 pm. Figure 3.6 shows the proportions of vehicle type groups during this period. Most of the vehicles (70%) were passenger vehicles, pick-ups or vans. Trucks with two or more units were the second most abundant vehicle type group (13%).

Based on visual observations of the license plates, vehicles traveling south were classified as 22.3% local and 77.7% non-local (N_{total} = 834). Vehicles traveling north were classified as 31.2% local and 68.8% non-local (N_{total} = 778).

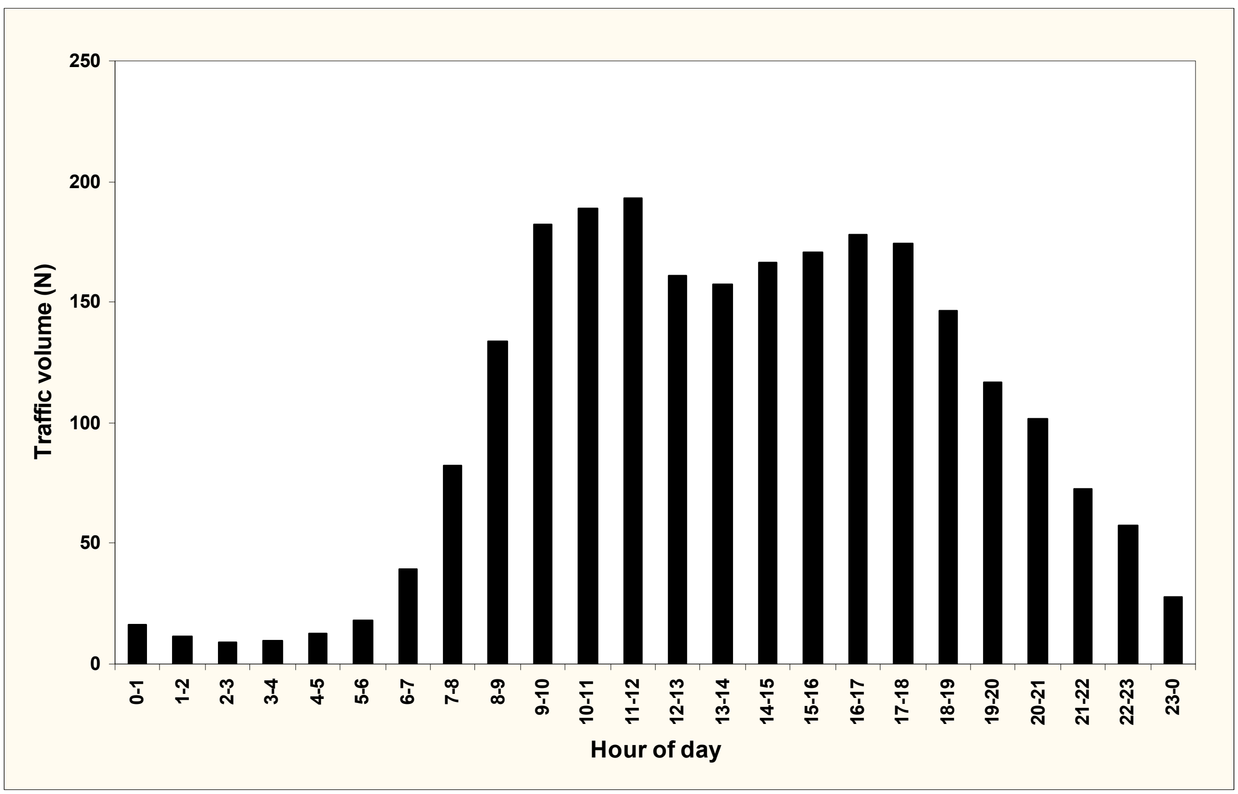

Figure 3.5: Average hourly traffic volumes between 13 and 27 June 2008 at the road section with the animal detection system

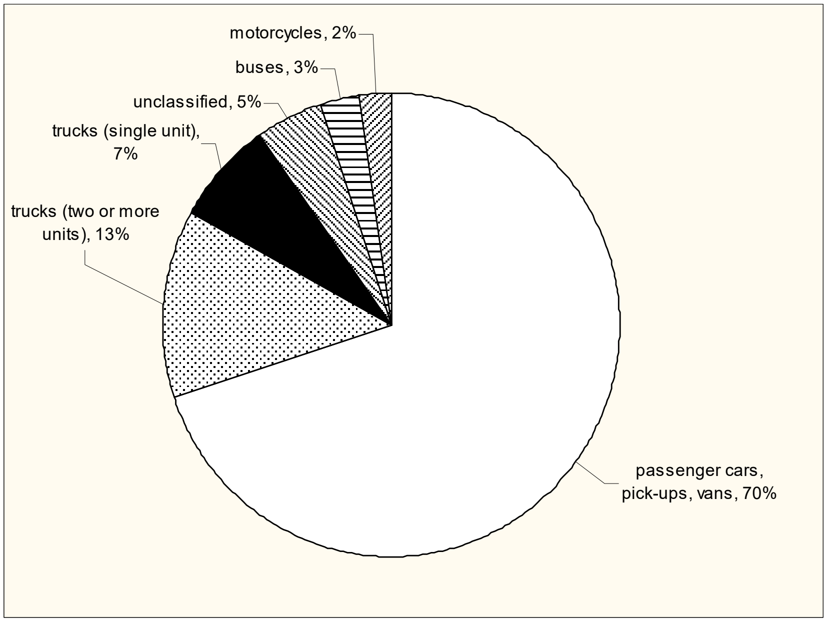

Figure 3.6: Vehicle type groups between 13 and 27 June 2008 traveling the road section with the animal detection system (N_{total} = 33,993)

3.3.2 Changes in vehicle speed

Passenger cars, pick-ups and vans traveling south changed their speed as they entered, traveled through, and left the road section with the animal detection system. Figures 3.7 and 3.8 show the changes in southbound speed for this vehicle type group during daylight and nighttime conditions respectively. With the warning beacons off, mean vehicle speed decreased when traveling through the animal detection area during the day (1.72 mi/h (2.77 km/h)) and at night (1.08 mi/h (1.74 km/h)). With the warning beacons on, mean vehicle speed decreased during the day (3.44 mi/h (5.53 km/h)), but it increased slightly at night (0.11 mi/h (0.18 km/h)). Mean vehicle speeds increased after leaving the animal detection area. In general, the mean vehicle speeds were lower with the warning beacons activated than with the warning beacons off.

ANOVA analysis of the interaction between counter location and the status of the warning lights showed that the change in vehicle speed was dependent on whether the warning lights were activated ($P<0.001$). ANOVA analysis of the interaction effect between counter location and visibility (day/night) showed that the change in vehicle speed was also dependent on visibility ($P=0.008$).

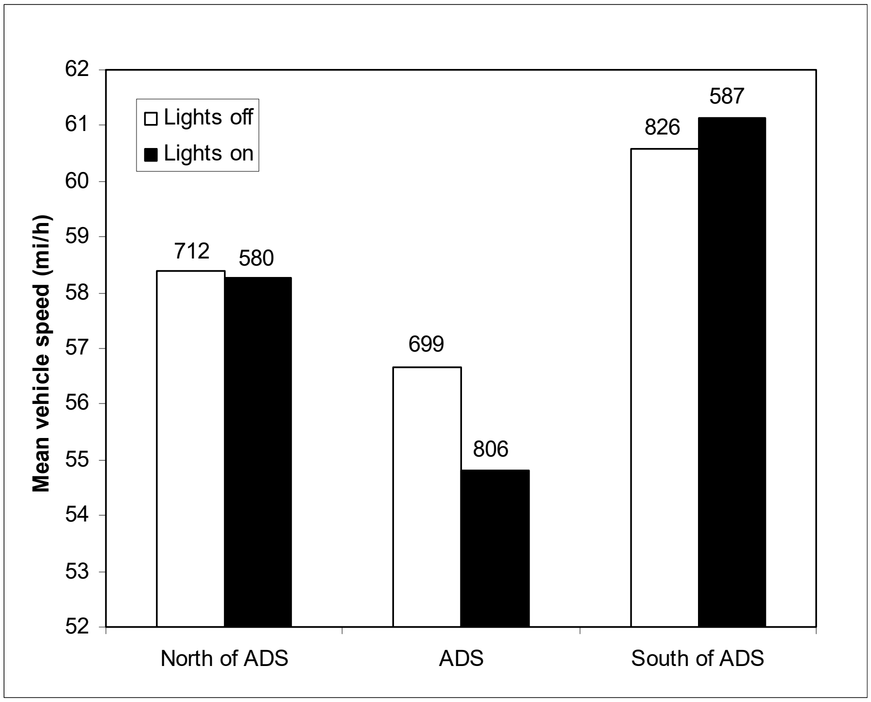

Figure 3.7: Changes in vehicle speed of passenger cars, pick-ups, and vans for <u>southbound</u> traffic during the <u>day</u> (with sample size shown above each bar)

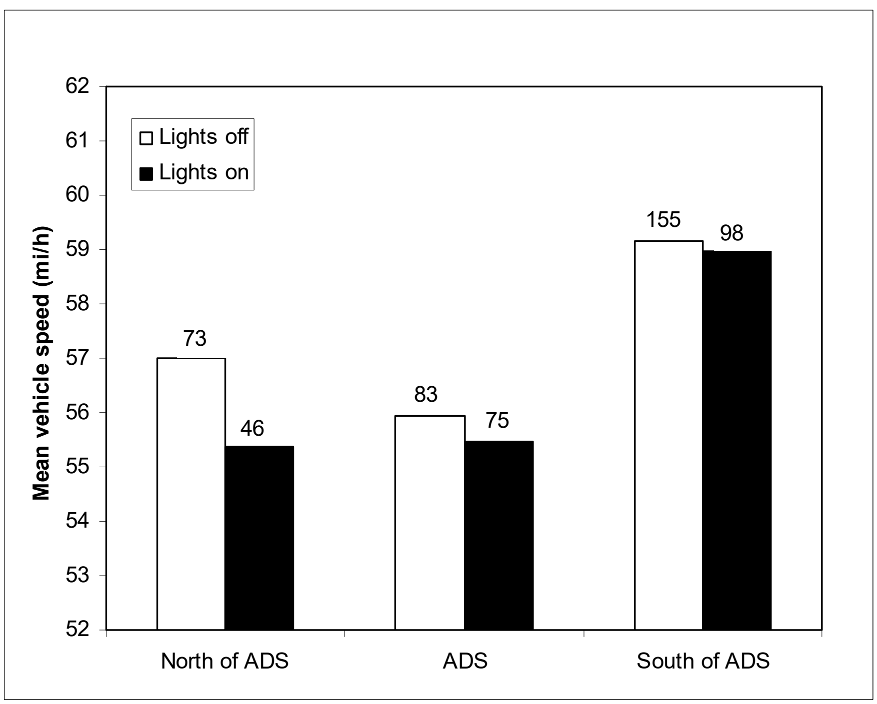

Figure 3.8: Changes in vehicle speed of passenger cars, pick-ups, and vans for <u>southbound</u> traffic during the <u>night</u> (with sample size shown above each bar)

Passenger cars, pick-ups and vans traveling north changed their speed as they entered, traveled through, and left the road section with the animal detection system. Figures 3.9 and 3.10 show the changes in northbound speed for this vehicle type group during daylight and nighttime conditions respectively. With the warning beacons off, mean vehicle speed increased when traveling through the animal detection area, (2.51 mi/h (4.04 km/h)) during the day and at night (1.66 mi/h (2.67 km/h)). With the warning beacons on, mean vehicle speed increased 1.47 mi/h (2.37 km/h) during the day and 3.55 mi/h (5.71 km/h) at night. Mean vehicle speeds tended to stay the same or increase after leaving the animal detection area. While speeds increased after vehicles entered the animal detection area, vehicle speed was lower with the warning beacons activated than with the warning beacons off. During daylight conditions vehicle speed was slightly higher after leaving the road section with activated warning beacons compared to inactive warning beacons.

ANOVA analysis of the interaction between counter location and the status of the warning lights showed that the change in vehicle speed was dependent on whether the warning lights were activated (P=0.001). ANOVA analysis of the interaction effect between counter location and visibility (day/night) showed that vehicle speed was also dependent on visibility (P<0.001).

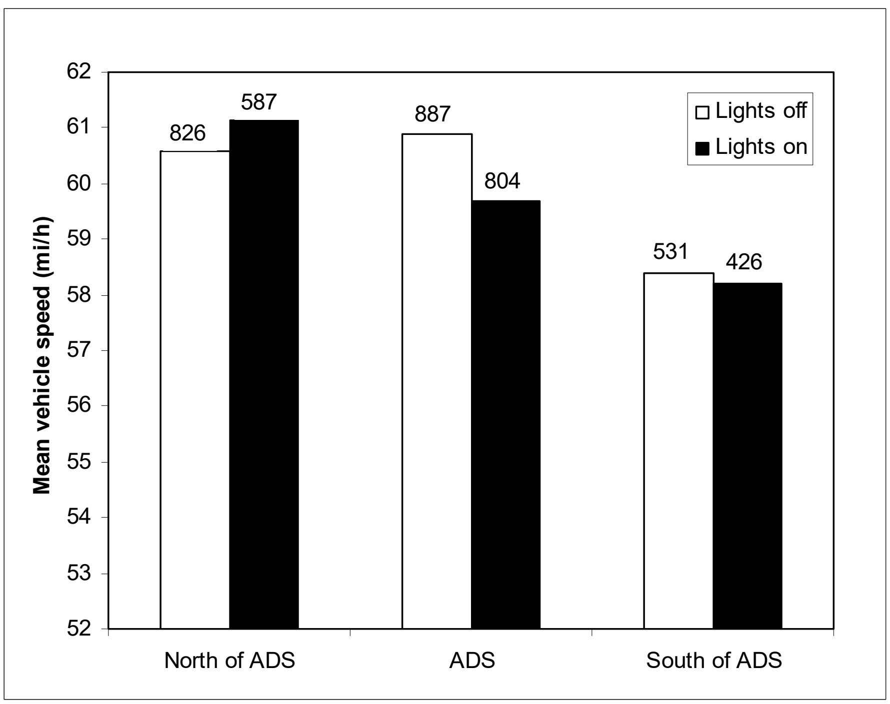

Figure 3.9: Changes in vehicle speed of passenger cars, pick-ups, and vans for northbound traffic during the day (with sample size shown above each bar)

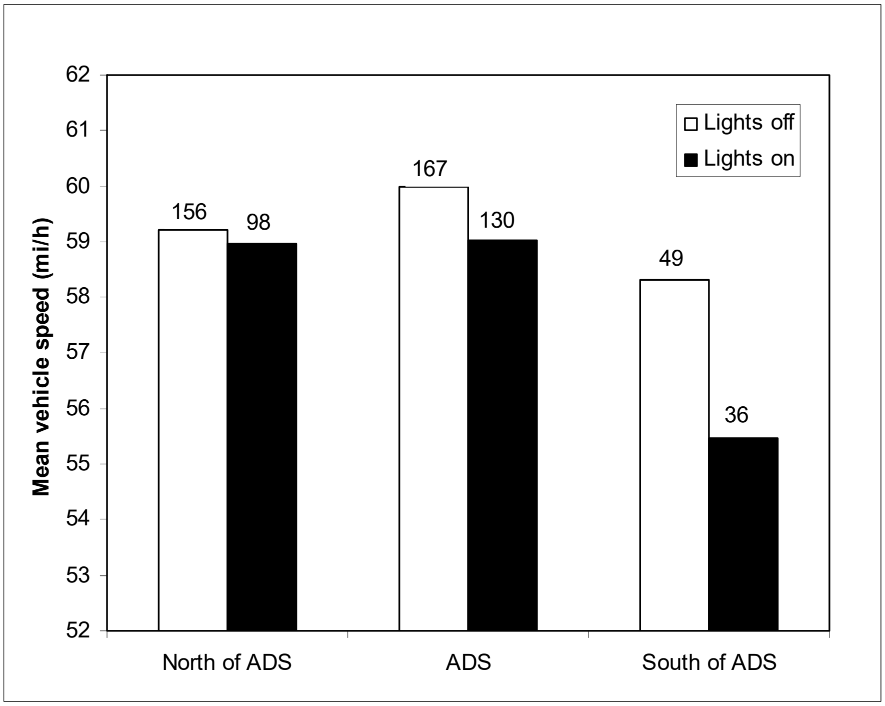

Figure 3.10: Changes in vehicle speed of passenger cars, pick-ups, and vans for northbound traffic during the night (with sample size shown above each bar)

3.3.3 Vehicle speed

Figures 3.11 and 3.12 show the mean vehicle speeds in both daylight and nighttime conditions of passenger cars, pick-ups and vans within the animal detection area for southbound and northbound traffic respectively. This vehicle type group had lower mean speeds with warning beacons activated compared to warning beacons off. For southbound traffic, the mean speed was 2.78 mi/h (4.47 km/h) lower during the day and 2.58 mi/h (4.15 km/h) lower during the night (ANOVA, main effect status warning signs, $P<0.001$). For northbound traffic, the mean speed was 0.29 mi/h (0.47 km/h) lower during the day and 1.34 mi/h (2.16 km/h) lower during the night (ANOVA, main effect status warning signs, $P=0.05$). For day and night combined, the mean vehicle speed was 2.76 mi/h (4.44 km/h) lower for southbound traffic and 0.41 mi/h (0.66 km/h) lower for northbound traffic with warning beacons activated. For both directions combined, the mean passenger car, pick-up and van speed was 1.52 mi/h (2.45 km/h) lower with warning beacons activated.

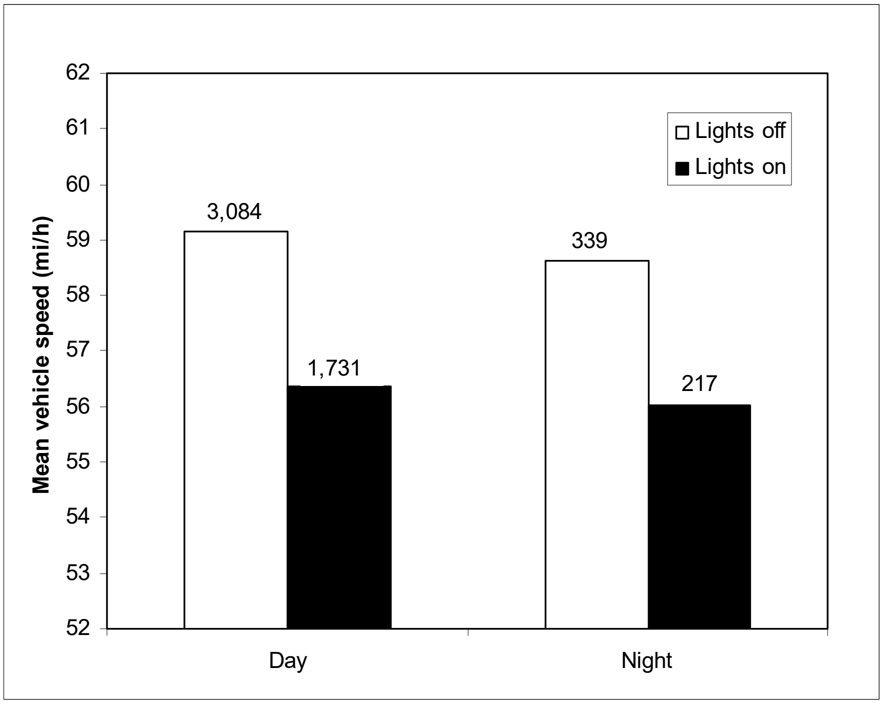

Figure 3.11: Vehicle speed of passenger cars, pick-ups, and vans for southbound traffic (with sample size shown above each bar)

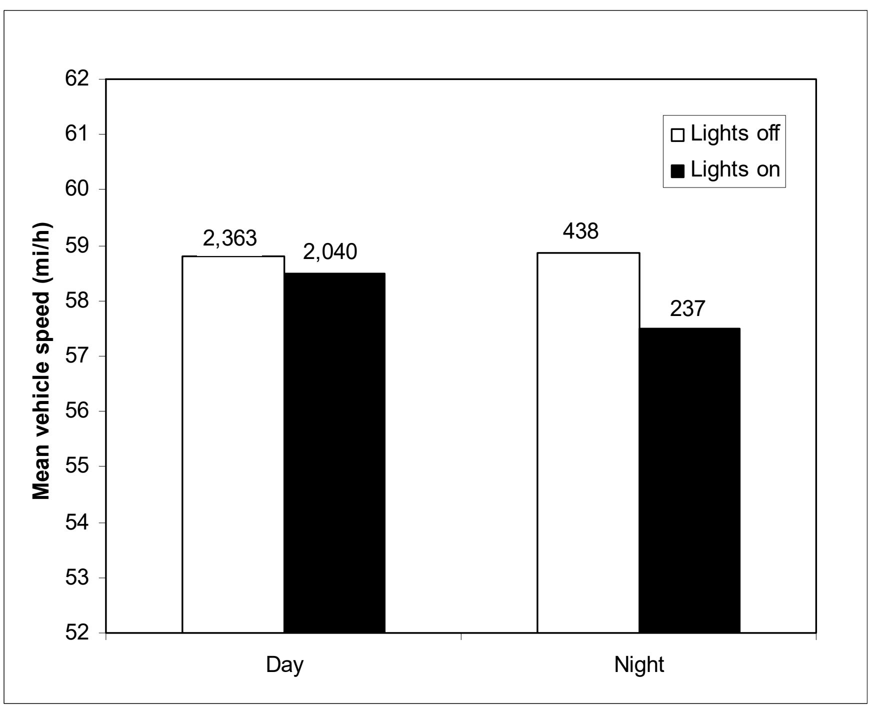

Figure 3.12: Vehicle speed of passenger cars, pick-ups, and vans for northbound traffic (with sample size shown above each bar)

Figures 3.13 and 3.14 show the mean vehicle speeds in both daylight and nighttime conditions of trucks with two or more units within the animal detection area for southbound and northbound traffic respectively. This vehicle type group also had lower mean speeds with warning beacons activated compared to warning beacons off. For southbound traffic, the mean speed was 1.32 mi/h (2.12 km/h) lower during the day and 1.09 mi/h (1.75 km/h) lower during the night (ANOVA, main effect status warning signs, P=0.011). For northbound traffic, the mean speed was 0.42 mi/h (0.68 km/h) lower during the day and 1.99 mi/h (3.20 km/h) lower during the night (ANOVA, main effect status warning signs, P=0.05). For day and night combined, the mean vehicle speed was 1.29 mi/h (2.08 km/h) lower for southbound traffic and 0.78 mi/h (1.26 km/h) lower for northbound traffic with warning beacons activated. For both directions combined, the mean truck speed was 0.91 mi/h (1.46 km/h) lower with warning beacons activated.

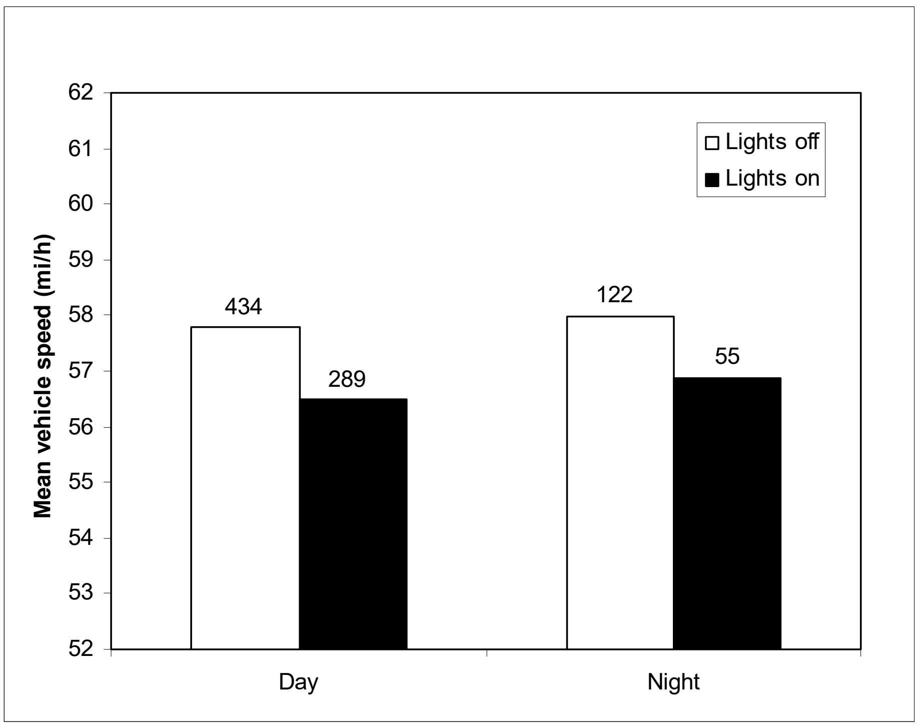

Figure 3.13: Vehicle speed of trucks with two or more units for <u>southbound</u> traffic (with sample size shown above each bar)

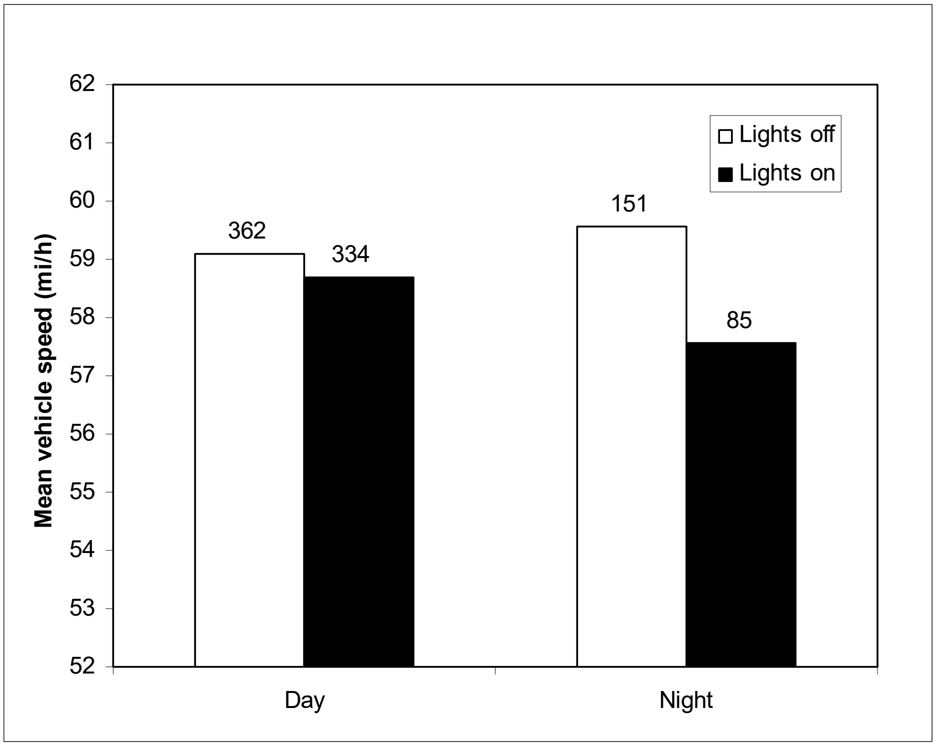

Figure 3.14: Vehicle speed of trucks with two or more units for northbound traffic (with sample size shown above each bar)

3.4 DISCUSSION

Southbound drivers reduced their speeds when traveling through the road section with the animal detection system, both with warning lights off and on. In contrast to the researchers' expectations, northbound drivers increased their speeds when traveling through the animal detection area, both with warning lights off and on. It is uncertain why the mean speeds of northbound traffic increased. Perhaps this increase in speed was related to the geometry of the road or the proximity of the boundary of the National Park two miles farther north.

Nonetheless, the Passenger cars, pick-ups, and vans Group, and the Trucks with two units or more Group had lower vehicle speeds with the warning lights activated compared to warning light off. For both travel directions combined, the speed of passenger cars, pick-ups, and vans was 1.52 mi/h (2.45 km/h) lower with the warning lights activated. The speed of trucks with two units or more was 0.91 mi/h (1.46 km/h) lower with warning lights activated.

While vehicles only reduced their speed by a few miles per hour, small reductions in vehicle speed are associated with a disproportionate decrease in the probability of severe accidents when traveling at high speed (*Kloeden, et al. 1997*). In addition, fewer or less severe wildlife-vehicle collisions may be attained not only through lower vehicle speed, but also through increased driver alertness (see Section 3.1). Warning signs with activated beacons are likely to make drivers more alert. Driver reaction time to an unusual and unexpected event can be reduced from 1.5 sec to 0.7 sec if drivers are warned (*Green 2000*). A constant passenger vehicle speed of 57.45 mi/h (92.44 km/h) with warning lights on leads to a potential reduction in stopping distance of 67.3 ft (20.5 m).

4.0 SYSTEM EFFECTIVENESS: COLLISIONS WITH LARGE MAMMALS

4.1 INTRODUCTION

The ultimate measure of the effectiveness of animal detection systems is whether they result in fewer collisions with large mammals. Kistler (*1998*), Romer and Mosler-Berger (*2003*), and Mosler-Berger and Romer (*2003*) published research on the number of animal-vehicle collisions before and after seven detection systems were installed in Switzerland. As shown in Table 4.1, these systems reduced the number of animal-vehicle collisions by 82% on average.[7] All seven sites showed a reduction in collisions after an animal detection system was installed, and three of the seven sites had not had a single collision six to seven years after system installation. The data relate to collisions with roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*). Collisions that occurred during the day when the systems were not active were excluded from the analyses.

While the sites with an animal detection system showed a strong reduction in the number of animal-vehicle collisions, the total number of animal-vehicle collisions in the wider region remained constant (*Kistler 1998*). This is further evidence that the reduction in collisions was indeed related to the presence of the animal detection systems and not the result of potential reductions of the ungulate populations or major changes in traffic volume and time of travel. Furthermore, detection data stored by the systems and tracking data confirmed that ungulates still frequented the sites (*Mosler-Berger and Romer 2003*).

Data from a site in Arizona (*Dodd and Gagnon 2008*) showed that elk-vehicle collisions were reduced from 11.7 per year on average to 1 per year after an animal detection system was installed in a gap in an electric fence (1 year of data post-installation). This was a 91% reduction in collisions with large animals.

[7] 1-sided Wilcoxon matched-pairs signed-ranks test, P=0.008, n=7. See Kistler (*1998*) for details on the seven sites and systems.

Table 4.1: Collisions with large animals before and after the installation of animal detection systems in Switzerland (based on *Mosler-Berger and Romer 2003*)

	Before			After			Reduction	
Location	**Collisions (N)**	**Yrs**	**Coll./yr**	**Collisions (N)**	**Yrs**	**Coll./yr**	**Coll./yr**	**%**
Warth	14	7	2.00	3	10	0.30	1.70	85.00
Soolsteg	8	11	0.73	1	6	0.17	0.56	77.08
Val Maliens	7	3	2.33	6	5	1.20	1.13	48.57
Marcau	12	4	3.00	6	5	1.20	1.80	60.00
Schafrein	26	8	3.25	0	6	0.00	3.25	100.00
Duftbächli	18	8	2.25	0	6	0.00	2.25	100.00
Grünenwald	6	8	0.75	0	7	0.00	0.75	100.00
Average reduction								81.52

Anecdotal data from other sites show the following:

- An animal detection system near Sequim, WA (see *Huijser, et al. 2006*), has led to a reduction in elk-vehicle collisions.[8]
- A site with the system near Clam Lake, WI (see *Huijser and Kociolek 2008*) has experienced two elk-vehicle collisions between 19 December 2006 (when the system became operational) and fall 2007 (*Clam Lake Elk News 2007*). During this same period the previous year there were five elk vehicle collisions; suggesting a 60% reduction in collisions with large animals.
- About 50% fewer white-tailed deer than expected were hit at a site near Marshall, MN (see *Huijser, et al. 2006*) between April 2007 (when the animal detection system became operational) and January 2008 (*CBS 2008*). Before the system became operational between 40 and 80 white-tailed deer were hit on the one-mile-long road section equipped with the system (*Star Tribune 2007*).

4.2 METHODS

This section discusses the research methods used to test the effectiveness of the animal detection system along US Highway 191 in Yellowstone National Park in reducing the number of collisions with large mammals.

[8] Personal communication, Shelly Ament, Washington Department of Fish and Wildlife; personal communication, David Rubin, Sequim Elk Habitat Committee.

4.2.1 Study design

Most studies that investigate the effect of animal detection systems on the number of collisions with large mammals analyze animal-vehicle collision data or road mortality data before and after the systems are installed. It is important that the data are collected for several years both before and after installation (comparison in time) as well as at the site with the animal detection system and on road sections in the surrounding area (comparison in space). Comparisons in time may be confounded by fluctuating animal populations, changes in traffic volume and time of travel, and changes in the landscape that may influence animal movement patterns to and from the road. Comparisons in space could be influenced by variability in site conditions, as well as other factors that may change or differ between the test and control sites.

For this study the researchers analyzed animal-vehicle collision data and road mortality records from the 1 mi (1,609 m) long road section equipped with the system (treatment section) as well as other sections on this road that served as a control. The animal-vehicle collision data and road mortality records were collected from 1998 through 2007.

4.2.2 Animal-vehicle collision data and road mortality data

The researchers received animal-vehicle collision data and road mortality data from the following sources:

- Yellowstone National Park: wildlife mortality records 1989 through 2007. The researchers selected road mortality records only from this data set.

- Montana Department of Transportation: carcass removal reports 1998 through 2007.

- Montana Department of Transportation: Montana Highway Patrol accident reports 1992 through 2007. The researchers selected animal-vehicle collision records only from this data set.

The researchers combined the data from the three sources for the ten-year period 1998 through 2007. Potential duplicates (multiple collision or carcass records that related to the same incident) were deleted from the data set by screening the data for records that were within 2 days and within 0.2 mi from each other.

The researchers only included data that occurred between the southern boundary of Yellowstone National park (mile reference post 11.0) and the entrance to Gallatin Canyon (mile reference post 71.0). Thus the data related to 60.0 mi (96.54 km) in total.

Two of the data sets, wildlife mortality records from Yellowstone National Park and carcass removal reports from the Montana Department of Transportation, included the species name of the animal involved in each collision. The third data set, the Montana Highway Patrol accident reports, did not include the species name of the animal involved.

The reported species in collisions occurring between mile reference posts 11.0 and 71.0 are shown in Figure 4.1. Elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), white-tailed deer

(*O. virginianus*), and moose (*Alces alces*) represented 81.9% of the reported collisions or mortality reports.[9]

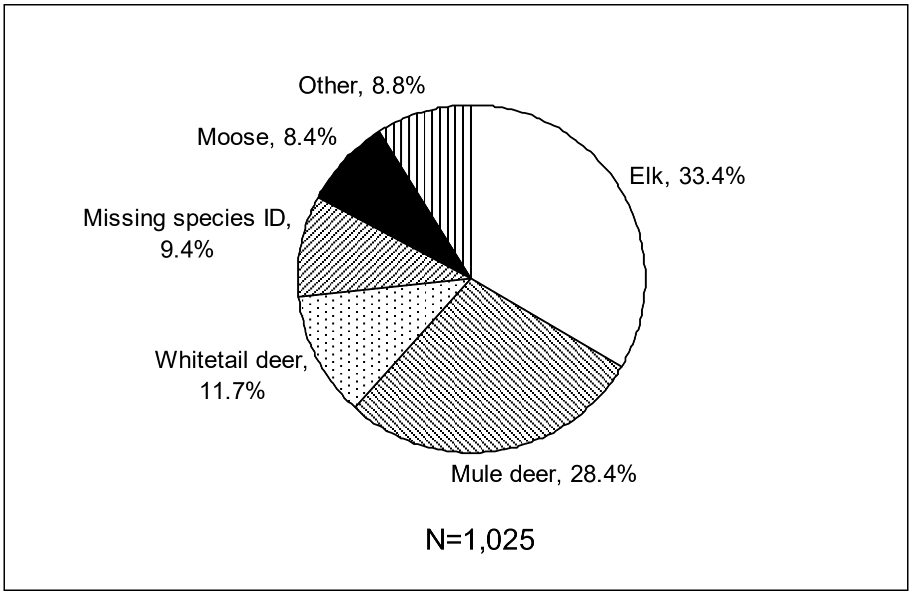

Figure 4.1: Species reported to be involved with wildlife-vehicle collisions along US Hwy 191, mile reference post 11.0 through 71.0, 1998 through 2007 (treatment section and all control sections combined)

The reported species from the treatment section (mile reference posts 28.0 through 29.0) are shown in Figure 4.2. Elk, mule deer, moose, coyote, and wolf represented 91.2% of the reported collisions or mortality reports.

[9] The category "other" for the entire road section between mile reference posts 11.0 and 71.0 included coyote (*Canis latrans*) (n=44, 4.29%), bighorn sheep (*Ovis canadensis*) (n=11, 1.07%), gray wolf (*Canis lupus*) (n=9, 0.88%), black bear (*Ursus americanus*) (n=7, 0.68%), beaver (*Castor canadensis*) (n=3, 0.29%), deer spp. (*Odocoileus spp.*) (n=2, 0.20%), bison (*Bos bison*) (n=1, 0.10%), bobcat (*Lynx rufus*) (n=1, 0.1%), grizzly bear (*Ursus arctos*) (n=1, 0.1%), mountain goat (*Oreamnos americanus*) (n=1, 0.10%), raccoon (*Procyon lotor*) (n=1, 0.10%), and species not listed as a standard category on the Montana Department of Transportation carcass removal form (n=9, 0.88%) (see also *Huijser, et al. 2007a*).

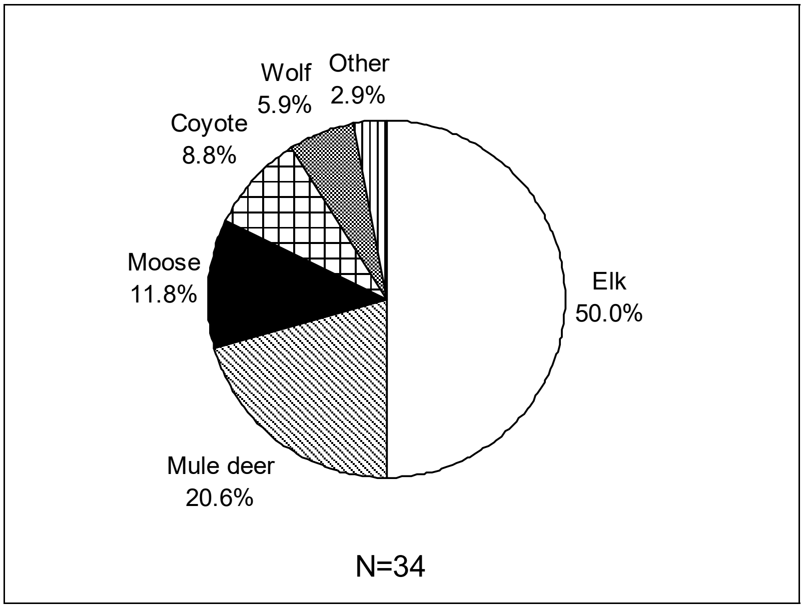

Figure 4.2: Species reported to be involved with wildlife-vehicle collisions along US Hwy 191, mile reference post 28.0 through 29.0, 1998 through 2007 (treatment section only)

For the investigation of the effectiveness of the system in reducing collisions the researchers only selected the records that related to large mammals, as the animal detection system was designed to detect large mammals only, primarily elk (*Huijser, et al. 2006*). The selected species included deer (white-tailed deer and mule deer), elk, moose, bighorn sheep, mountain goat, bison, black bear and grizzly bear. However, the researchers also included all Montana Highway Patrol accident reports. Since these animals were apparently large enough to have resulted in human injuries, human fatalities or at least $1,000 in vehicle repair costs (see *Huijser, et al. 2007a*), it was assumed that the animals were also large enough to have been detected by the animal detection system.

4.2.3 Treatment section and control sections

The animal detection system installed between mile reference posts 28.0 and 29.0 in October/November 2002 was the "treatment" section (*Huijser, et al. 2006*). Various technical and design problems were identified and addressed before the system became fully operational on 18 January 2007. The system remained in full operation until it was removed on 18 August 2008.

In both the treatment section and the control sections the location of the collisions and road mortalities were estimated to the nearest 0.1 mi (160.9 m), based on the mile reference posts which were spaced at about 1.0 mi (1,609 m). As shown in Figure 4.3, however, the collision and road mortality data were more often reported to the nearest whole- or half-mile point rather than to the nearest tenth-mile.

Since the treatment section was 1.0 mi long, the researchers included all collision and carcass data reported for mile reference posts 28.0 through 29.0. Given the likelihood that many of the reported locations were approximated, though, the data were likely to have related to a longer road section, perhaps extending as much as 0.3 mi (483 m) beyond the whole mile reference posts on either side.

Because the treatment section began and ended at whole mile reference posts, and because the collision and carcass data were biased towards the whole (and half) mile reference posts, the functional analysis units, for both the treatment section and all the control sections (N=59), ran from each whole mile reference post to the next reference post.

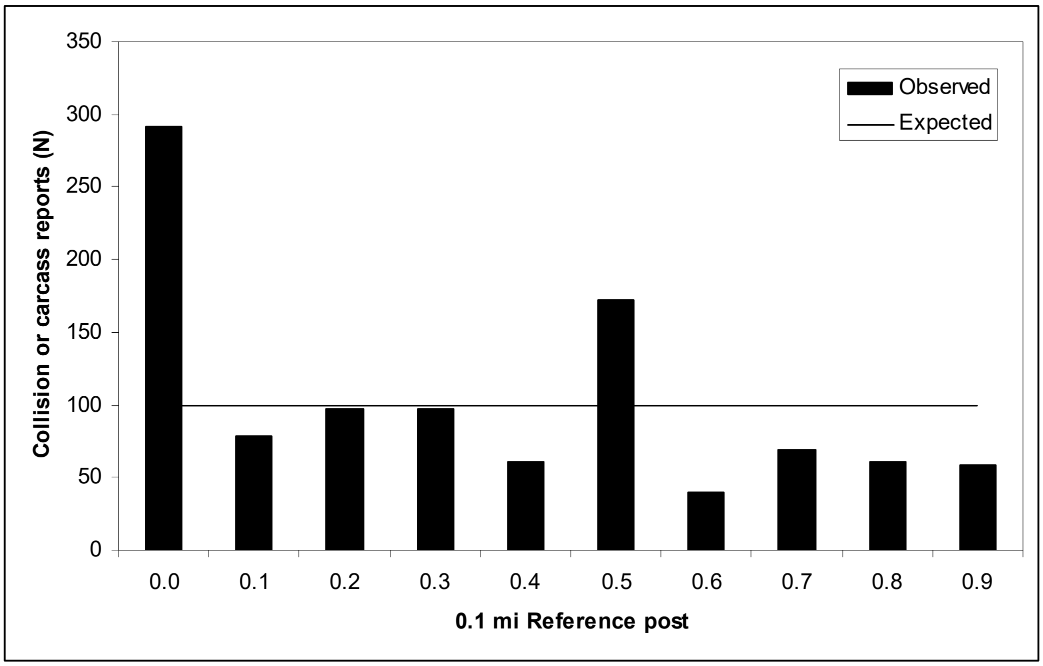

Figure 4.3: Observed and expected frequency distribution (N_{total} = 1,025) of animal-vehicle collision data and road mortality data (Pearson's Chi-square-test, χ^2=179.61, 9 d.f., p<0.001). Note: This analysis was conducted for all reported collisions and road mortalities, regardless of the size of the species.

4.3 RESULTS

4.3.1 Comparison in time

Figure 4.4 shows the average number of reported collisions with large mammals and large mammal road mortalities in the treatment section before and after the activation of the animal detection system. In the years 1998-2006, before the animal detection system became fully operational, the treatment section had an average of 3.0 reported collisions and mortalities. In 2007, when the system was fully operational, one large mammal road mortality (an elk) was reported from the treatment section. This number was 66.7% lower than might be expected, based on the average from previous years.

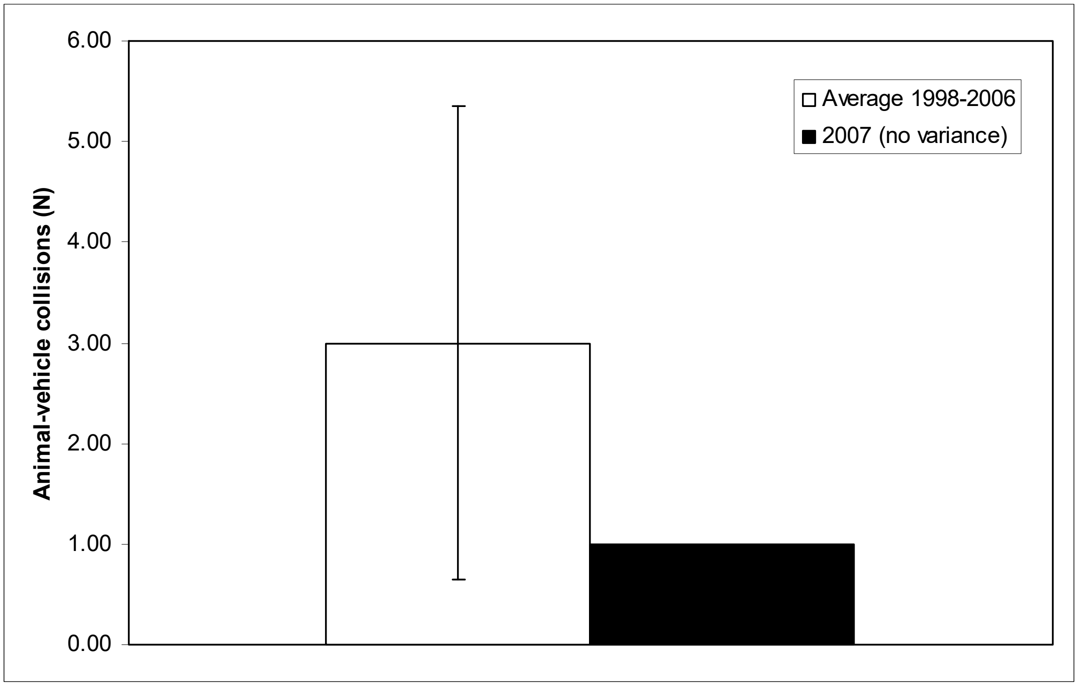

Figure 4.4: Average number (± SD) of reported collisions with large mammals and large mammal road mortalities from the treatment section before and after the system became fully operational

4.3.2 Comparison in space

Figure 4.5 shows the annual reported collisions with large mammals and large mammal road mortalities in the control sections (N=59) and the treatment section before and after activation of the animal detection system. Before the system became fully operational (1998 through 2006) the average number in the 59 control sections was about two per year. The average in the treatment section was much more variable, mostly because the treatment section included only a one-mile road section. After the system became fully operational (2007), the number of reported collisions or road mortalities in the treatment section was 34.6% lower than in the control sections.

Not all control sections, however, were comparable to the treatment section in the number of reported collisions and road mortalities. Therefore the researchers selected 11 control sections that had had a similar average number of reported collisions and road mortalities (2.6 - 3.4) to that of the treatment section (3.0) in the years 1998 through 2006. The researchers then calculated the average number for these control sections in 2007 and compared it to the number for the treatment section. The findings are shown in Figure 4.6. While the system was operational the number of reported collisions and road mortalities in the treatment section was 57.6% lower than the average in the selected control sections.

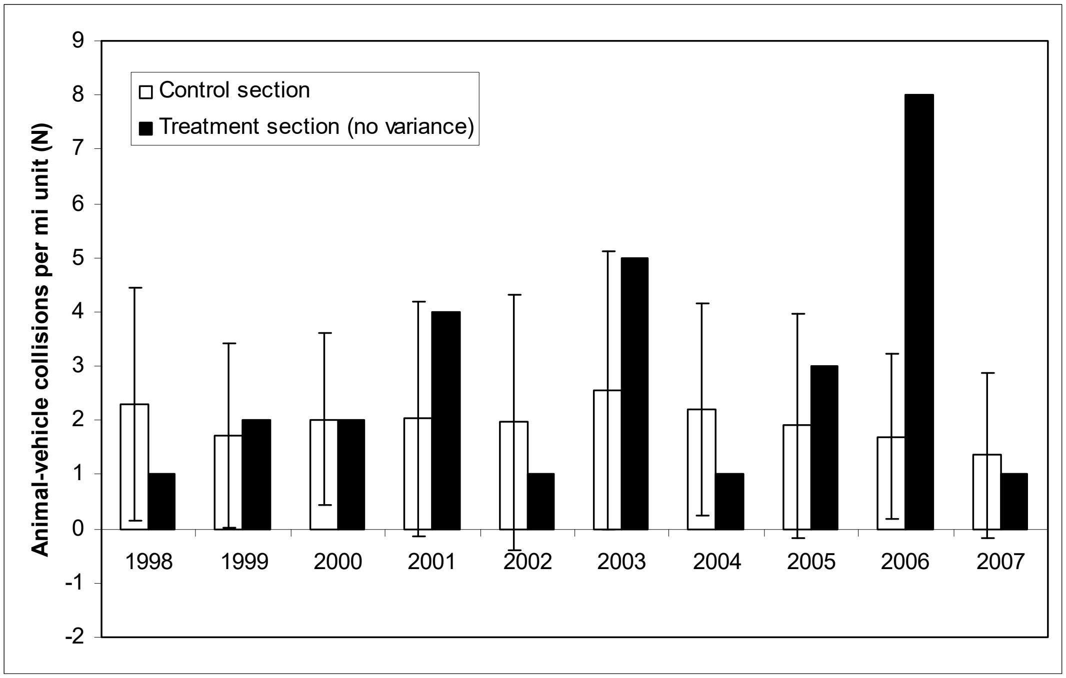

Figure 4.5: Average number (± SD) of reported collisions with large mammals and large mammal road mortalities from the control sections (N=59) and the treatment section before and after the system became fully operational

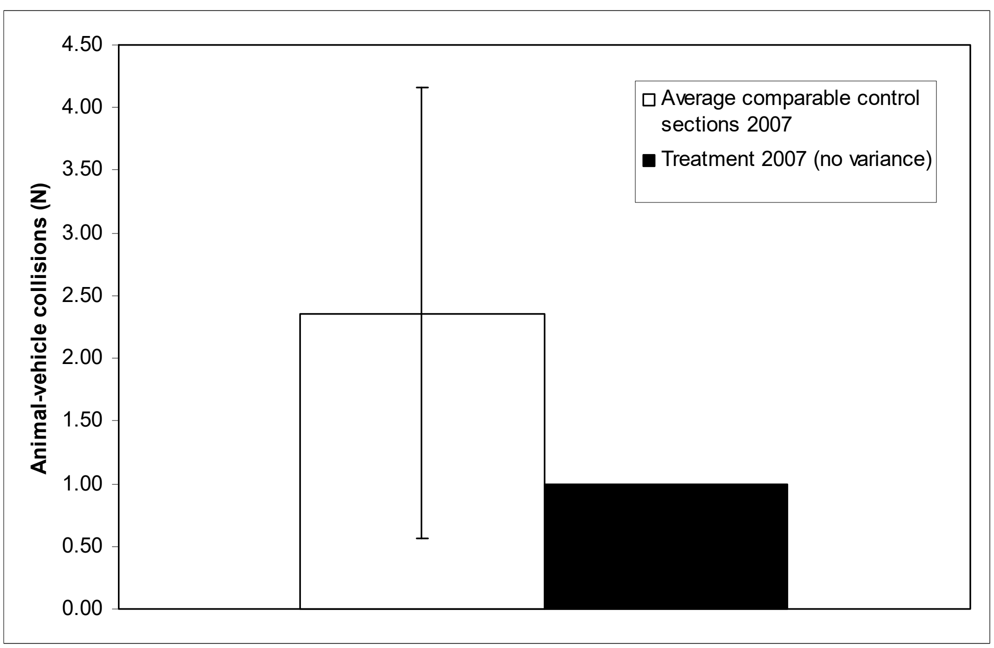

Figure 4.6: Average number (± SD) of reported collisions with large mammals and large mammal road mortalities from selected comparable control sections (N=11) and the treatment section while the system was fully operational

4.4 DISCUSSION

The number of reported collisions with large mammals and large mammal road mortalities from the treatment section after the system became operational was 66.7% lower than the nine-year average before the system became operational. While the system was operational the number of reported collisions with large mammals and the number of large mammal road mortalities in the treatment section was 57.6% lower than in comparable control sections. While both the comparison in time and space suggest that the animal detection system resulted in fewer collisions with large mammals, the short (one-mile) length of the treatment section combined with the limited time of data collection (one year) while the system was operational do not allow for a statistical test and a firm conclusion. Nonetheless, the available literature on the effectiveness of animal detection systems in reducing collisions with large mammals is consistent with the findings of this study, supporting a conclusion that animal detection systems indeed result in fewer collisions with large mammals.

5.0 SYSTEM ACCEPTANCE BY THE TRAVELING PUBLIC

5.1 INTRODUCTION

For an animal detection system to be effective, the system needs to detect the target species reliably, and drivers need to respond to the activated warning signals, either through increasing their alertness, reducing vehicle speed, or a combination of the two (see Figure 3.1). Driver response to activated warning signs is critical to the effectiveness of animal detection systems. Figure 5.1 illustrates the desired driver response to the activated warning signal. In this chapter the researchers report on a survey of the traveling public to gauge their experiences with and opinions on the animal detection system along US Highway 191 in Yellowstone National Park between West Yellowstone and Big Sky, Montana.

Figure 5.1: A bull elk (in velvet) approached the system on 25 April 2007, and activated the warning signs. The activated warning signs in combination with the high visibility of the elk next to the road resulted in vehicles braking and reducing speed (Personal observation Marcel Huijser, WTI-MSU) (Photo: Marcel Huijser, WTI-MSU).

5.2 SURVEY METHODS

The survey took place between 24 August 2007 and 3 August 2008, and was aimed at the public, aged 18 years or older, who traveled this particular road section. (The survey instrument is included in Appendix C.) The survey was voluntary and anonymous and was delivered via an internet website, direct interviews along the roadside, and mail. Flyers with the website address were distributed at gas stations and other locations in West Yellowstone and Big Sky (5 locations in each town). In addition, the website for the survey was advertised in local and regional media. The flyer and media ads contained a brief background of the project and a link to a website for the survey.

Direct interviews were conducted at a gas station in Big Sky. Figure 5.2 shows the booth where the interviews were conducted. If travelers wanted to participate in the survey but did not have time to complete the survey at that time, they were provided with the option to fill out the survey on the website or fill out a hard copy of the survey and return it by mail.

Figure 5.2: Booth set up for conducting surveys at a gas station in Big Sky, MT (Photo: Angela Kociolek, WTI-MSU)

The survey questionnaire provided a brief background on the project, a photo of the animal detection system, and instructions for filling out the questionnaire. More detailed information about animal detection systems and the historical wildlife-vehicle collision data for the road section concerned was provided at the end of the questionnaire.

There were 160 responses in total – 66 from the website, 86 from roadside interviews, and 8 from mailed responses. Not all respondents answered every one of the 24 survey questions. The researchers treated unanswered questions as "missing data;" these were not included in the results. The actual sample size is always indicated in the results presented below, allowing the reader to see how many of the 160 respondents chose to answer the individual questions. Some of the multiple choice survey questions included an option where the respondents could indicate that they did not want to answer that question or that they did not know. These answers were included in the results.

5.3 SURVEY RESULTS

The responses to each question in the survey, including individual comments from the interviewees, are located in Appendix D. This section only highlights the topics that are of greatest interest. For the complete survey results, please refer to Appendix D.

Question 7 in the survey asked, "Have you noticed the animal detection system and/or the accompanying warning signs?" The distribution of responses is shown in Figure 5.3. Nearly all respondents had indeed observed the animal detection system and/or the associated warning signs.

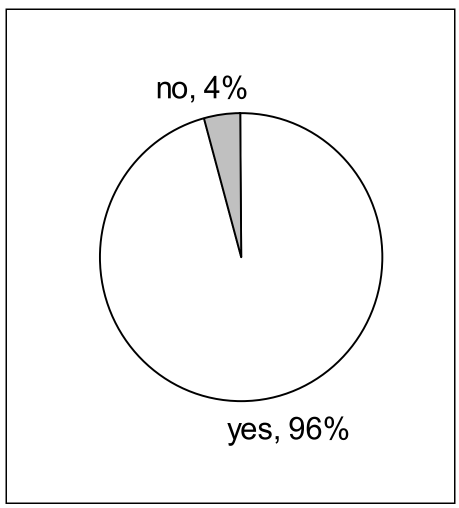

Figure 5.3: Respondents who noticed the animal detection system and/or accompanying warning signs (N=145)

Question 8 in the survey asked, "What do you think the message is when the warning signs are flashing (= activated)?" As shown in Figure 5.4, the activated warning signs were correctly interpreted by 39% of the respondents – that animals may be present on or near the road. Since the warning signs may have also been activated by something else besides large mammals, they did not necessarily mean that there actually were large animals on or near the road. Overall, 91% of the respondents were apparently aware that the signs referred to animals on or near the road in this area.

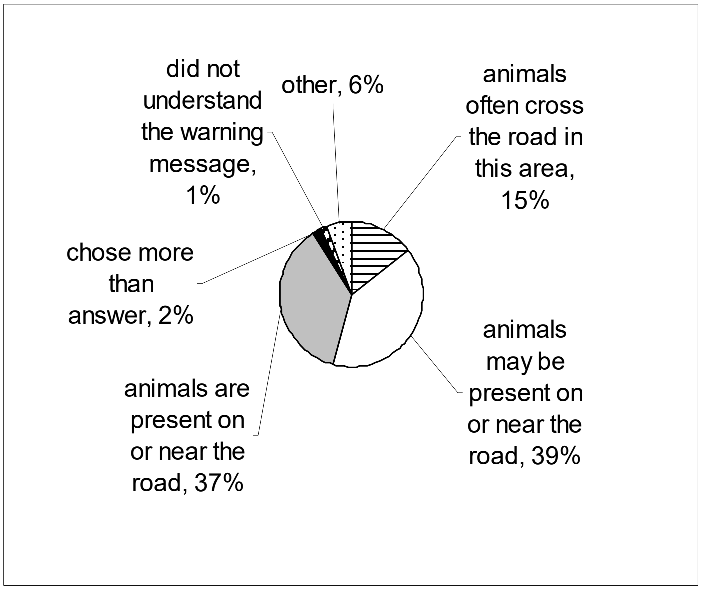

Figure 5.4: Respondents' interpretations of the activated warning signs (N=142)

Question 9 in the survey asked, "What do you think the message is when the warning signs are NOT flashing (=NOT activated)?" As shown in Figure 5.5, the non-activated warning signs were correctly interpreted by 64% of the respondents – that animals may still be present on or near the road, and that animals often cross the road in this area. However, 17% of the respondents thought that there were no animals present on or near the road or did not understand the message.

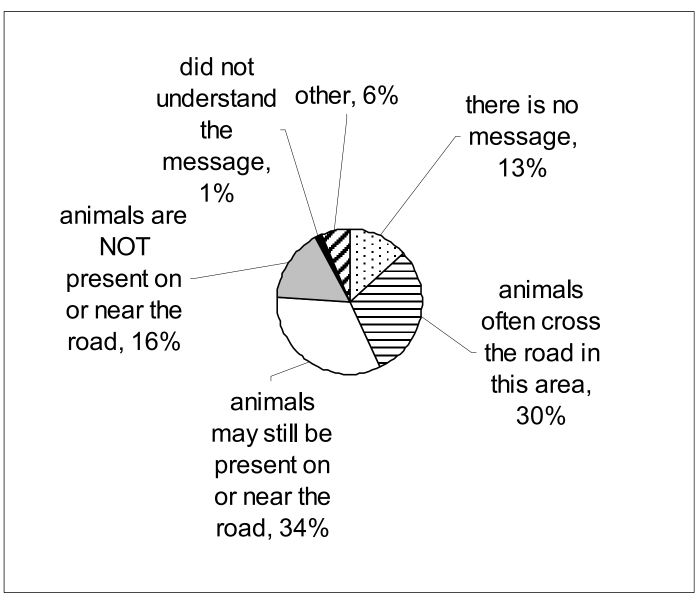

Figure 5.5: Respondents' interpretations of the non-activated warning signs (N=142)

Question 10 in the survey asked, “Would you like to see the animal detection system along US Hwy 191 removed or stay in place?” Figure 5.6 shows the results. A majority of the respondents (59%) wanted to see the animal detection system stay in place.

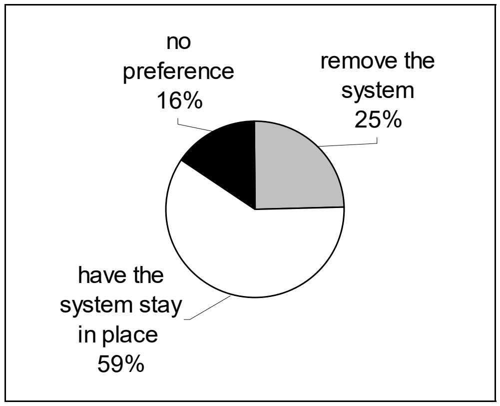

Figure 5.6: Respondents’ wishes on retaining or removing the animal detection system (N=141)

Question 15 in the survey asked, “If the warning lights were flashing (=activated), how did you respond to seeing the activated warning signals? (Please check all that apply).” As shown in Figure 5.7, most respondents (85%) stated that they either reduced the speed of their vehicle or became more attentive when the warning signs were activated.

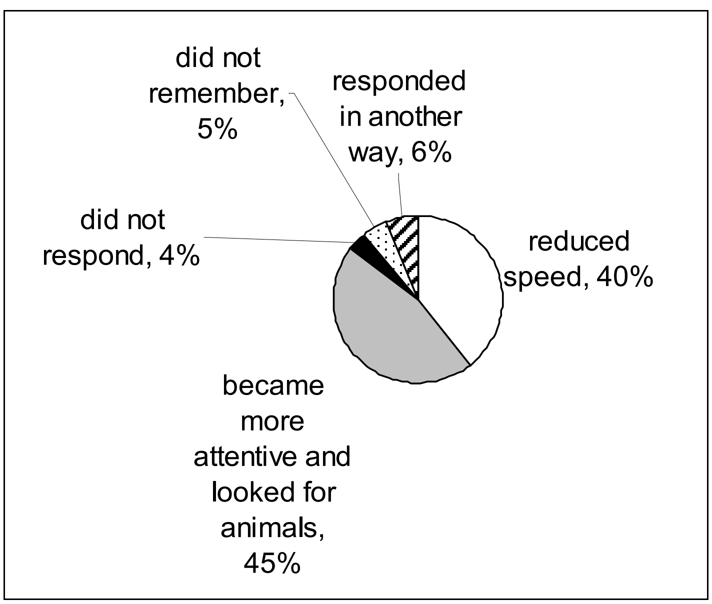

Figure 5.7: Responses to the activated warning signs (N=64)

In analyzing the responses to this question, the researchers divided respondents into two groups – "infrequent travelers" of the road section with the animal detection system (once a year or less, and 2-12 times per year) and "frequent travelers" (2-4 times per month, and 2 or more times per week). Figures 5.8 and 5.9 show the responses of these two groups to the activated warning signs.

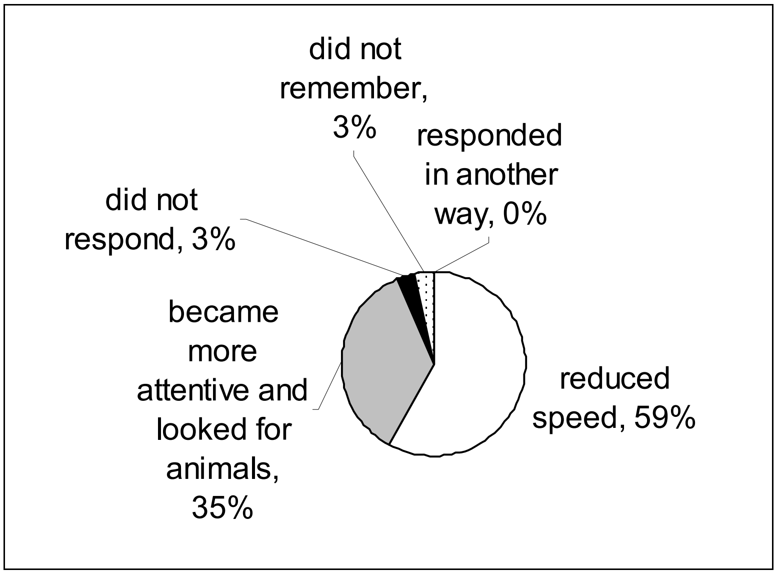

Figure 5.8: Responses to the activated warning signs by <u>infrequent</u> travelers (N=31)

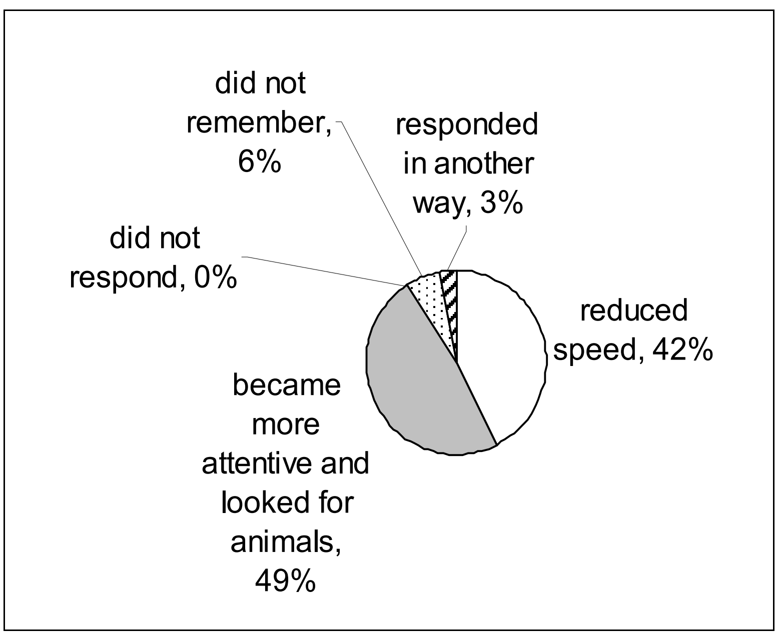

Figure 5.9: Responses to the activated warning signs by <u>frequent</u> travelers (N=33)

The results showed that among both infrequent and frequent travelers, most reported to have reduced their vehicle speed or increased their alertness. However, a larger percentage of infrequent travelers reported to have reduced vehicle speed than frequent travelers, and more frequent travelers reported to have increased their alertness than infrequent travelers.

Question 16 in the survey asked, “Do you feel the animal detection system was helpful in this situation?” As shown in Figure 5.10, about half of the respondents (52%) found the system helpful when the warning signs were activated.

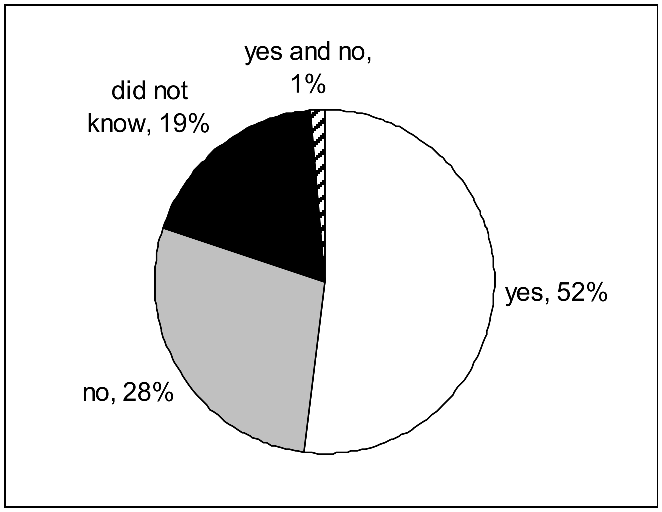

Figure 5.10: Opinions on the helpfulness of the system in that situation (N=75)

Question 18 in the survey asked, “Do you think animal detection systems are a good idea? This question relates to animal detection systems in general, not the one along US Hwy 191 in specific.” Figure 5.11 shows the results. Most of the respondents (71%) thought the concept of animal detection systems was a good idea.

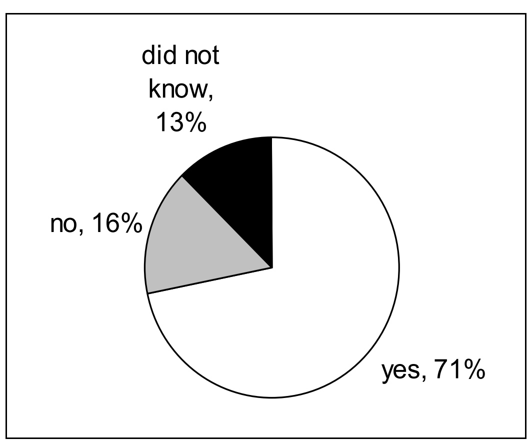

Figure 5.11: Opinions of respondents on whether animal detection systems are a good idea (N=152)

Question 19 in the survey asked, “Animal detection systems are designed to warn you when animals are on or near the roadway. For you to be confident in such a system, what percentage of large animals (deer and larger) that approach the road do you think should be detected by an animal detection system?” The results are shown in Figure 5.12, with the number of respondents in each percentage category. About half of the respondents (51%) expected animal detection systems to detect all (i.e., 100%) (32%) or nearly all (i.e., 91-99%) (19%) of the large animals that approach the road. Over two-thirds (68%) expected animal detection systems to detect more than 80% of large animals approaching the road.

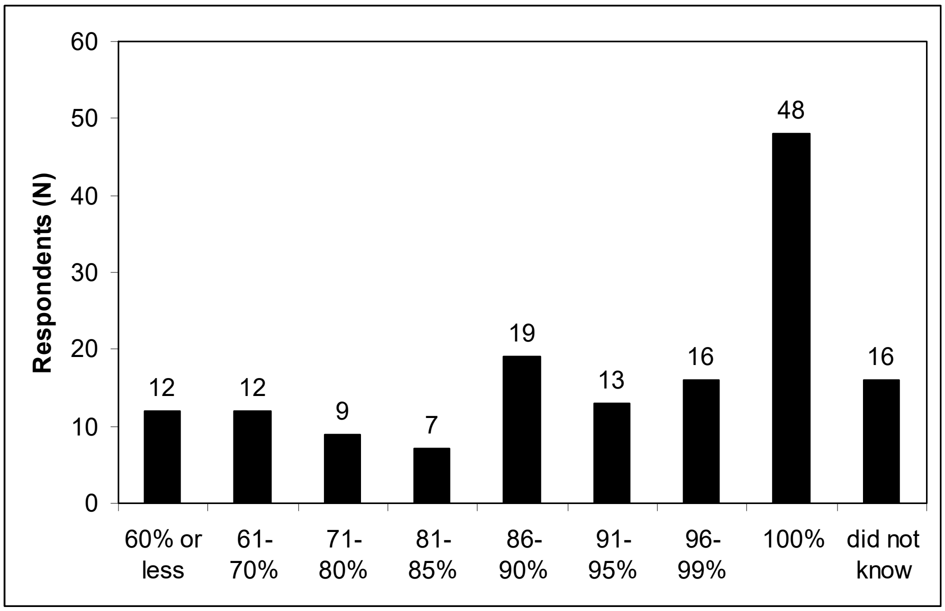

Figure 5.12: Opinions on the percentage of large animals (deer and larger) that should be detected when they approach the road (N=152)

Question 20 in the survey asked, “Certain weather conditions, low flying birds, falling leaves or high vegetation can result in a “detection” and the activation of the warning signs. What percentage of the total number of detections would you allow to be “false” (that is, the warning lights are on, but there is not really a large animal present)?” Figure 5.13 shows the results, with the number of respondents in each percentage category. About half of the respondents (52%) would allow for no more than 20% of all detections to be false (i.e., not related to large animals).

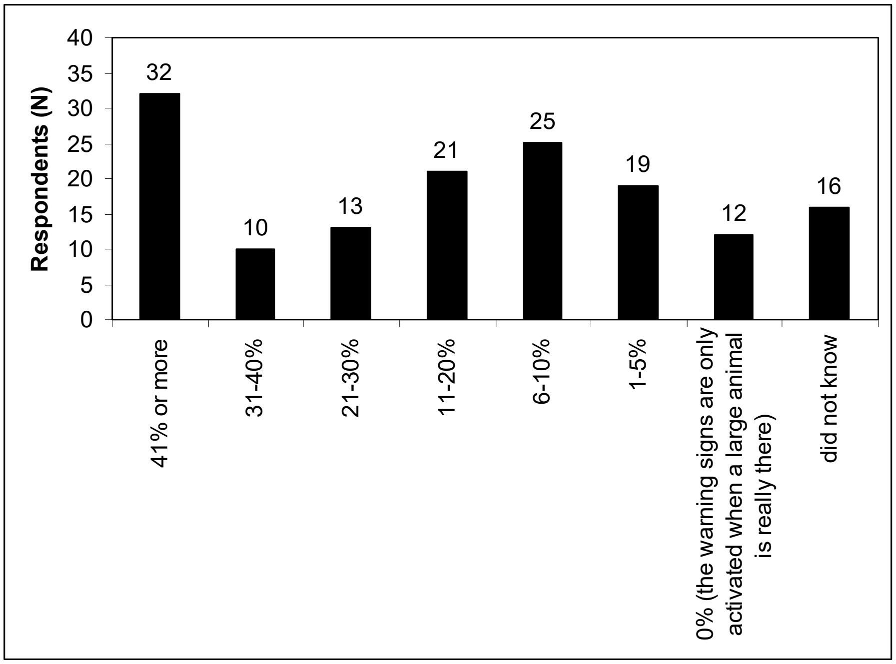

Figure 5.13: Percentage of detections that respondents would allow to be "false" (N=148)

Question 21 in the survey asked, "What percentage reduction in collisions with large wildlife (deer and larger) would you want to see or expect to see as a result of the presence of an animal detection system?" Figure 5.14 shows the results, with the number of respondents in each percentage category. Most respondents (60%) expected animal detection systems to reduce collisions with large animals by 71% or more.

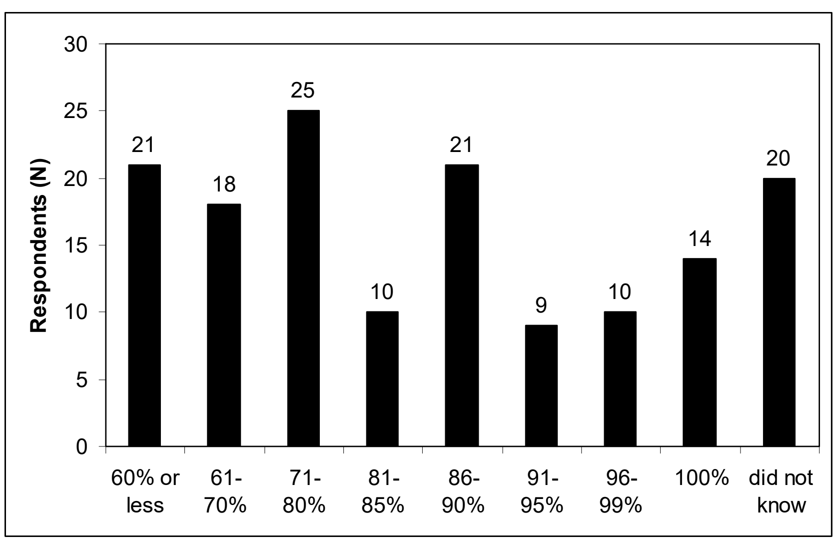

Figure 5.14: Percentage reduction in collisions with large wildlife species that respondents would like to see as a result of an animal detection system (N=148)

Question 23 in the survey asked, "Please rank the importance of potential improvements of animal detection systems. Use a five-point scale where 1 means it is not important and 5 means that it is very important. (Circle one number per question)." Figures 5.15 through 5.18 show respondents' opinions on the importance of four types of potential improvements – reliability, understandability, size and cost. For most respondents it was very important to have reliable animal detection systems and clear and easy to understand warning signals (Figure 5.15 and 5.16). On the other hand small, unobtrusive, and inexpensive animal detection systems were moderately important to very important for most respondents (Figures 5.17 and 5.18).

a. Reliable systems

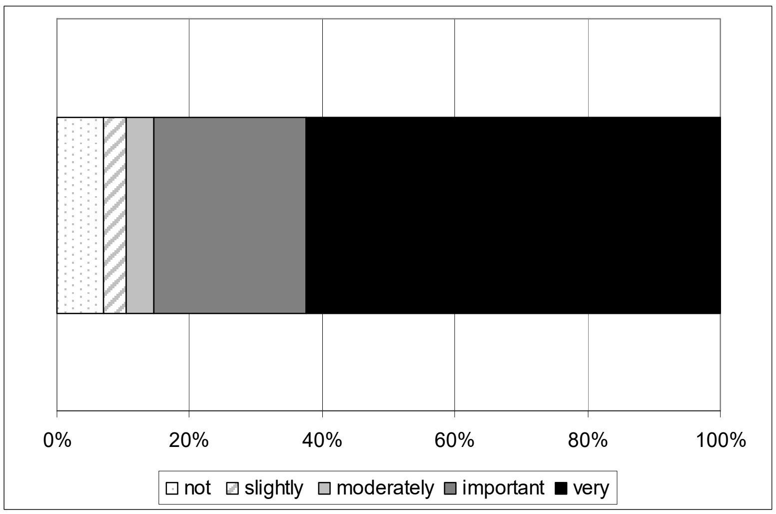

Figure 5.15: Importance of improvements in system reliability (N=144)

b. Clear, easy to understand warning signals

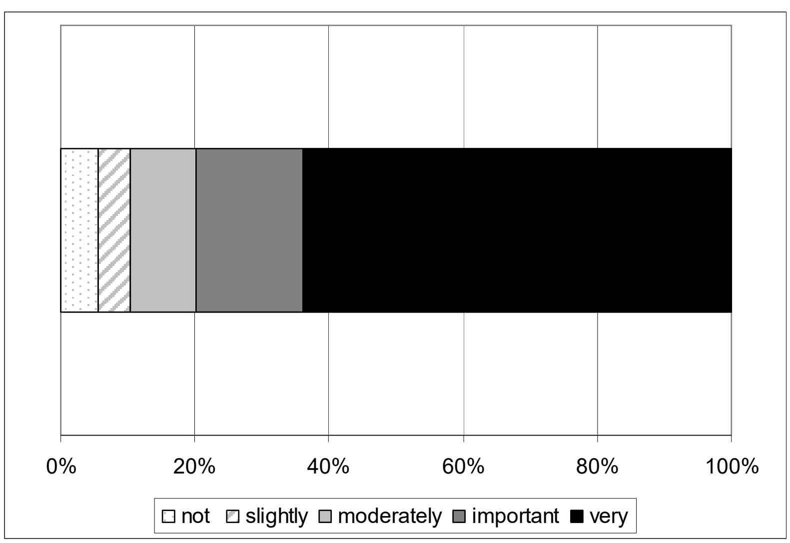

Figure 5.16: Importance of clear and easy to understand warning signals (N=144)

c. Small, unobtrusive systems

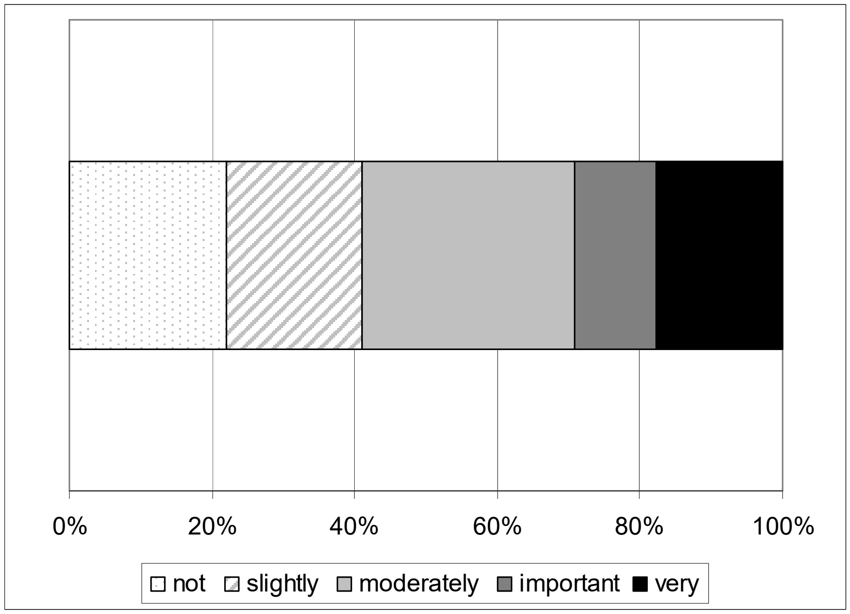

Figure 5.17: Importance of small and unobtrusive systems (N=141)

d. Inexpensive systems

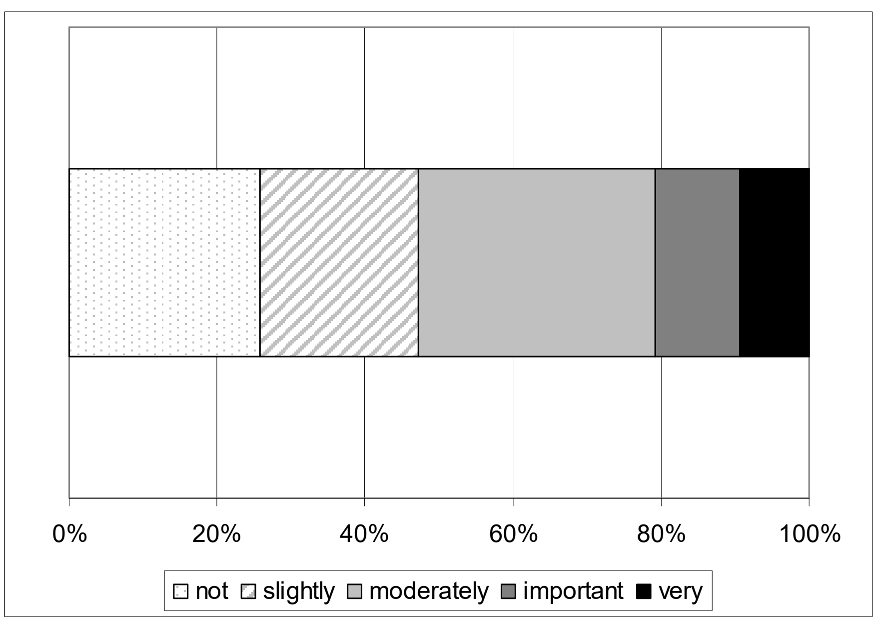

Figure 5.18: Importance of inexpensive systems (N=140)

5.4 DISCUSSION

As mentioned above, Appendix D contains the detailed results of the traveler survey. The authors would like to highlight the following results of the survey. A majority of respondents:

- Were 25-64 years of age (87%); those 25-44 years of age totaled 41%, and those 45-64 years of age totaled 46%;
- Were male (71%);
- Drove a pickup, SUV or van (58%) between Big Sky and West Yellowstone 2-12 times per year or more (89%); and had done so within the past 30 days (75%);
- Often or always worried about hitting large ungulates on the road (81%);
- Noticed the animal detection system (96%);
- Interpreted the signs to mean that large animals either may be or were on or near the road in this area when the warning signs were activated (91%);
- Reduced their speed (40%) or became more alert (45%) as a result of the activated warning signs; however, a larger percentage of infrequent travelers reported to have reduced vehicle speed than frequent travelers, and a larger percentage of frequent travelers reported to have increased their alertness than infrequent travelers;
- Thought the system was helpful when it was activated (52%);
- Wished to see the US Highway 191 system stay in place (59%);
- Thought animal detection systems were a good idea, in general (71%);
- Expected animal detection systems to detect all (32%) or nearly all (91-99%) (19%) large animals that approach the road;
- Would allow for no more than 20% of all detections to be false (i.e., not related to large animals) (52%);
- Expected animal detection systems to reduce collisions with large animals by 71% or more (60%);
- Found it very important to make potential improvements in the reliability of animal detection systems (63%); and
- Found it very important to have clear and easy to understand warning signals (64%).

However, the authors would also like to emphasize that:

- A portion of the respondents (17%) thought there were no animals on or close to the road or did not understand the message when the warning signs were not activated, perhaps leading to an absent or wrong driver response (less alert, faster vehicle speed); and
- The respondents who were critical about the animal detection system along US Highway 191 in Yellowstone National Park expressed concerns about the reliability of the system, the costs of this type of mitigation measure, and how the system affected landscape aesthetics.

6.0 SUMMARY AND CONCLUSIONS

6.1 SUMMARY AND CONCLUSIONS OF PHASE II

The summary and conclusions of Phase II of the Animal-Vehicle Crash Mitigation Using Advanced Technology Study are organized according to the objectives of the project.

- Modify the system so that the blind spots cover 2-5% of the total length of the system at the most, install remote access to the system through a satellite connection, and make other repairs and modifications as necessary.
- Conduct further tests on system reliability.
- Investigate the effectiveness of the system with regard to reduction of vehicle speed in response to activated warning signs.
- Investigate the effectiveness of the system with regard to the number of collisions with large animals.
- Investigate the acceptance of the system by drivers, the Montana Department of Transportation, and Yellowstone National Park.
- Remove the system by 31 August 2008, as a condition set by Yellowstone National Park.

6.1.1 Blind spots and remote access

Objective: Modify the system so that the blind spots cover 2-5% of the total length of the system at the most, install remote access to the system through a satellite connection and make other repairs and modifications as necessary.

The system was modified and repaired, as reported in Chapter 2. After system modifications, blind spots covered 1.09% of the total length of the system, surpassing the stated objective. Remote access through a satellite connection was achieved, not only allowing for a higher intensity of system monitoring, but also allowing for the warning signs to be manually turned on or off, either for research or management purposes.

6.1.2 System reliability

Objective: Conduct further tests on system reliability.

System monitoring revealed that various parts of the system showed ongoing wear and tear and that replacement parts were sparse or not available. This led to repairs rather than replacements, and relatively intensive monitoring of the system for potential new problems. Mainly because of the experiences at the study site, the vendor (STS, now ICx Radar Systems) has developed a more integrated, more compact, and more robust animal detection system. This should result in a smaller footprint and a reduced impact on landscape aesthetics, more reliable operation (fewer false positives and false negatives), longer life span, and greater distance between the sensors and associated equipment (see also *Huijser, et al. 2006*).

6.1.3 System effectiveness – vehicle speed

Objective: Investigate the effectiveness of the system with regard to reduction of vehicle speed in response to activated warning signs.

Southbound traffic reduced speed when traveling through the road section with the animal detection system, both with warning lights off and on. Northbound traffic increased speed when traveling through the road section with the animal detection system, both with warning lights off and on. It is uncertain why northbound traffic increased speed. Perhaps this increase in speed related to the geometry of the road, sight distance, or the proximity of the boundary of Yellowstone National Park two miles farther north. Nonetheless, passenger cars, pick-ups, and vans, and trucks with two units or more all had lower vehicle speed with the warning signs activated compared to warning signs off. For both travel directions combined, the speed of passenger cars, pick-ups, and vans was 1.52 mi/h (2.45 km/h) lower with warning signs activated. The speed of trucks with two units or more was 0.91 mi/h (1.46 km/h) lower with warning signs activated.

While vehicles only reduced their speed a few miles per hour, reductions in vehicle speed are associated with a disproportionate decrease in the probability of severe accidents when traveling at high speed (*Kloeden, et al. 1997*). In addition, fewer or less severe wildlife-vehicle collisions may not only be achieved through lower vehicle speed, but can also be achieved through increased driver alertness. 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 sec to 0.7 sec if drivers are warned (*Green 2000*). Thus a constant passenger vehicle speed of 57.45 mi/h (92.44 km/h) when the warning lights were on indicated a potential reduction in stopping distance of 67.3 ft (20.5 m).

6.1.4 System effectiveness – animal-vehicle collisions

Objective: Investigate the effectiveness of the system with regard to the number of collisions with large animals.

The number of reported collisions with large mammals and the number of large mammal road mortalities from the treatment section after the system became operational was 66.7% lower than before the system became operational. The number of reported collisions with large mammals and the number of large mammal road mortalities from the treatment section after the system became operational was 57.6% lower than in comparable control sections.

While the comparisons in time and space suggest that the animal detection system resulted in fewer collisions with large mammals, the relatively short road length of the treatment section combined with only one year of data collection after the system became operational did not allow for a test of the statistical significance of these findings; thus no firm conclusion can be drawn. Nonetheless, the findings of this study are consistent with the available research that suggests that animal detection systems indeed result in fewer collisions with large mammals. It is important to note though that an animal detection system must be detecting large animals reliably before one investigates the effectiveness of a system in reducing collisions with large mammals.

6.1.5 System acceptance

Objective: Investigate the acceptance of the system by drivers, the Montana Department of Transportation, and Yellowstone National Park.

Most drivers who responded to the survey and who drove the road section with the animal detection system a) often or always worried about hitting large ungulates on the road (81%); b) noticed the animal detection system (96%); c) interpreted the signs to mean that large animals may be or were on or near the road in this area when the warning signs were activated (91%); and d) reduced their speed (40%) or became more alert (45%) as a result of the activated warning signs.

Most respondents a) thought the system was helpful when it was activated (52%); b) would like to see the US Highway 191 system stay in place (59%); and c) thought animal detection systems were a good idea, in general (71%). Most respondents a) expected animal detection systems to detect all (32%) or nearly all (91-99%) (19%) large animals that approach the road; b) would allow for no more than 20% of all detections to be false (i.e., not related to large animals) (52%); and c) expected animal detection systems to reduce collisions with large animals by 71% or more (60%). Most respondents found it very important to make potential improvements in the reliability of animal detection systems (63%), and found it very important to have clear and easy to understand warning signals (64%).

However, 17% of the respondents thought there were no animals on or close to the road or did not understand the message when the warning signs were not activated, perhaps leading to an absent or wrong driver response (less alert, faster vehicle speed). Respondents who were critical of the animal detection system along US Highway 191 in Yellowstone National Park expressed concerns about the reliability of the system, the costs of this type of mitigation measure, and the effect of the system on landscape aesthetics.

The Montana Department of Transportation was concerned about the reliability and robustness of the animal detection system and maintenance effort (see also *Huijser, et al. 2006*). While the system proved to detect elk reliably (see also *Huijser, et al. 2006*), the requirements for system coverage were met, and remote access through satellite was established to facilitate system monitoring and system management, substantial concerns remained with regard to the wear and tear of the system, the associated level of system monitoring, and lack of spare parts. This caused MDT to support system removal after completion of the research project.

Yellowstone National Park was mostly concerned about landscape aesthetics (see also *Huijser, et al. 2006*). For Yellowstone National Park, system removal was a condition for Phase II of the project.

6.1.6 System removal

<u>Objective</u>: Remove the system by 31 August 2008, as a condition set by Yellowstone National Park.

On 18 August 2008 the first sensors were removed. System removal, in accordance with the guidelines from Yellowstone National Park for subsoil, topsoil and vegetation, was completed on 12 September 2008.

6.2 ACCOMPLISHMENTS AND DISAPPOINTMENTS

After review of the findings and conclusions of the study, the researchers and funders identified the following accomplishments and disappointments of Phases I and II of this project.

6.2.1 Accomplishments of the project

- Animal detection system technologies and vendors were identified across North America and Europe.
- Vendors were stimulated to further develop animal detection systems and have the reliability of their systems evaluated.
- Experiences and opinions on the implementation and operation of animal detection systems were documented, and lessons learned were formulated.
- One of the two animal detection system technologies investigated for this project eventually proved to be able to reliably detect large mammals that approach the road.
- The effectiveness of animal detection systems in reducing collisions with large mammals was reviewed. Overall, different studies indicated that animal detection systems appear to reduce wildlife-vehicle collisions substantially (50-91%).
- Important insight was gained on the expectations of the public with regard to potential future minimum reliability standards for animal detection systems. This may guide further development of animal detection systems and help stakeholders discuss and agree on potential future standards.
- Important insight was gained on the expectations of the public with regard to the effectiveness of animal detection systems in reducing wildlife-vehicle collisions. This may help evaluate whether animal detection systems fulfill expectations of stakeholders.
- Animal detection systems can help society save money rather than be a cost to society on road sections that have a relatively high concentration of large mammal-vehicle collisions.

- Awareness of animal detection systems by the public and agencies (transportation and natural resource management agencies) is increasing, partially as a result of this project (see Appendix E).

- The number of locations where animal detection systems are installed in North America is increasing, partially as a result of this project. In addition, the number of animal detection system technologies and vendors is increasing (see Appendix E).

6.2.2 Disappointments

- System development and deployment on the two study locations took much more effort and time than expected (*Huijser, et al. 2006*).

- After the system along Highway 191 in Yellowstone National Park was implemented, it took substantial effort and about two years' time to identify technical problems and to modify the detection technology before the system reliably detected elk (*Huijser, et al. 2006*).

- Design errors caused blind spots where large animals could approach the road undetected (see also *Huijser, et al. 2006*). Correction of the blind spots led to increased expenses and further delays.

- Not all project partners fully realized that the project was a research project rather than the implementation of a tried and proven technology, causing differences in expectations for the project (*Huijser, et al. 2006*).

- The delays in correcting the blind spots and finalizing other system modifications reduced the time allotted for the evaluation of the effectiveness of the system in Phase II of the project, thus resulting in data too limited for any statistical analysis.

7.0 RECOMMENDATIONS

7.1 INTRODUCTION

Based on the experiences of this study, based on the synthesis of experiences by others in Europe and North America (see Huijser, et al. 2006; Huijser and Kociolek 2008), and based on experiences with other animal detection system projects (see e.g., *Huijser, et al. 2007b*), the researchers have formulated two sets of recommendations:

- Step-by-step recommendations for agencies considering the installation of an animal detection system alongside a road (adapted from *Huijser, et al. 2006*); and
- Recommendations for the future research and monitoring of the reliability and effectiveness of animal detection systems.

This chapter presents and discusses those recommendations.

7.2 RECOMMENDED STEPS FOR AGENCIES CONSIDERING IMPLEMENTING ANIMAL DETECTION SYSTEMS

If a transportation agency is interested in deploying an animal detection system, the following steps are recommended:

Step 1. Define the problem.
Define the problem to be solved (e.g., target species, parameters of effectiveness). Identify the requirements of the transportation agency (e.g., desired level of effectiveness, maximum maintenance effort). Identify the site specific conditions and requirements (e.g., slopes, curves, vegetation, minimum distance from the road, vegetation management restrictions). Ideally this step should be an outcome of a regional prioritization process, identifying current animal-vehicle collision hot spots or habitat linkage zones and potential future changes to animal movement due to changes in land use.

Step 2. Obtain an overview of all effective mitigation measures.
Obtain a current overview of all mitigation measures that are known to address the problem, that meet the requirements of the transportation agency, and that match the site specific conditions and requirements. Determine whether an animal detection system is indeed the most appropriate mitigation measure. While an animal detection system can be applied as a standalone mitigation measure, it can also be used in combination with other mitigation measures such as wildlife fencing and wildlife crossing structures (see *Huijser, et al. 2006* for examples).

Step 3. Obtain an overview of all animal detection systems.
Obtain a current overview of all animal detection systems – their vendors, system reliability, system effectiveness, other aspects of operation and maintenance, and other lessons learned.

Step 4. Select a system.
Select a system that meets the requirements of the transportation agency and that matches the site specific conditions and requirements. Not all reliable or effective systems may be suitable. Ideally, systems should meet minimum standards for system reliability. Such standards, however, have not been established at this time; therefore, no system has yet been tested with regard to such minimum requirements. If no reliability data are available, consider a two-phased contract with the vendor. The first phase would entail a beta test of the system in a smaller temporary installation to determine system reliability prior to a more permanent roadside installation in the second phase.

Step 5. Take lessons from other projects into account.
Take the lessons learned from this project and others into account (see summary in *Huijser, et al. 2006*) when preparing project descriptions, contracts and other agreements with vendors, installation contractors, researchers, and other project partners. In addition, consider what the most effective warning signs may be, and adhere to potential future standards for warning signs for animal detection systems.

Step 6. Prepare for technical difficulties, delays, and maintenance.
Prepare for technological difficulties and substantial delays following the installation of an animal detection system. It may take many months or years before an animal detection system becomes operational. Even systems that are initially successful will fail without proper monitoring and maintenance. Also prepare for potential abandonment of the project and system removal.

Step 7. Make a realistic risk assessment.
Make a realistic risk assessment for potential delays, technological challenges, the financial situation of a vendor, and political support for the project. If the outcome of the assessment is not acceptable, consider alternative mitigation measures.

Step 8. Conduct system acceptance tests.
Once an animal detection system technology has been implemented alongside a road, limited further reliability tests and reliability monitoring are required. Immediately after installation, basic system functioning should be evaluated before the warning signs or lights are attached and drivers are exposed to the warning signs. These “system acceptance tests” can include triggering the system at regular intervals (e.g., by using a human as a model for large mammal species), to ensure that each detection zone is operational and that no blind spots are present where the target species can approach the road undetected. In addition, patterns in the detection data can be analyzed for unexpected patterns (e.g., detections that do not match the knowledge on when and how much animals move in the road section concerned).

To facilitate system acceptance tests and further monitoring of system reliability and operation, it is advisable that an animal detection system saves all individual detections with a date and time stamp and detection zone in a log. Having remote access to the detection log, or a summary of the reliability and status parameters of the system, (e.g., through satellite connection) can make the monitoring of system reliability and system status more practical. An automated screening process of the reliability and status parameters, which would alert managers when these parameters are outside of previously defined ranges, would be ideal.

Step 9. Document and publish experiences.
Document and publish the experiences with the project, including lessons learned during design and planning, installation, and operation and maintenance, regardless of whether the project results in a reliable or effective system. This provides essential guidance for similar projects in the future.

Step 10. Document and publish data on system reliability and system effectiveness.
Document and publish data on system reliability and system effectiveness, regardless of whether the project results in a reliable or effective system. This will allow transportation agencies to compare the effectiveness of animal detection systems to other mitigation measures and to select the most reliable and effective animal detection systems.

7.3 RECOMMENDATIONS FOR FUTURE RESEARCH AND MONITORING

Recommendation 1: Measure system reliability.
Measure the reliability of each animal detection system, unless the reliability in detecting large mammals has already been investigated and reported on by an independent entity. An example of a project that aims to measure the reliability of animal detection systems is the effort at the transportation research facility "TRANSCEND" in Lewistown, central Montana (*Huijser, et al. 2007b*). As new manufacturers enter the market and as newer technologies become available, a continued need for investigating system reliability is likely.

Recommendation 2: Standardize how system reliability is measured.
If the reliability of different animal detection systems is to be compared, it is extremely important to standardize the way system reliability is measured (see *Huijser, et al. 2007b* for examples). Reliability parameters should include parameters that address false positives (e.g., a detection is reported, but there is no large animal present), false negatives (i.e., a large animal is present but is not detected), and downtime (i.e., the system is not functioning properly and therefore not detecting the target species). This type of research should preferably be conducted in a controlled access environment and not along a roadside. It is good practice to install an animal detection system along a roadside only after the system is known to be reliable.

Recommendation 3: Investigate the influence of environmental conditions.
Investigate the effect environmental conditions may have on the reliability of animal detection systems. Different detection technologies are affected in different ways by different environmental conditions. This information is likely to be important when selecting a suitable detection technology for a given set of environmental conditions at a particular location. This type of research should preferably be conducted in a controlled access environment and not along a roadside. An example of a project that aims to investigate the effect of environmental conditions on the reliability of animal detection systems is the effort at the transportation

research facility "TRANSCEND" in Lewistown, central Montana (*Huijser, et al. 2007b*). A weather station in the vicinity of the test bed collects detailed and frequent data on the environmental conditions in the area, allowing the researchers to relate the reliability performance of individual systems to these conditions.

Recommendation 4: Suggest and adopt minimum norms for system reliability.
Part of the project reported on by Huijser, et al. (*2007b*) investigates the opinions of transportation agency personnel, natural resource management agency personnel, the public, and researchers and manufacturers involved with animal detection systems, with regard to minimum norms for the reliability of animal detection systems. The data were investigated for potential overlap between the stakeholders to suggest minimum standards for the reliability of animal detection systems. The final report of this study was expected in the fall of 2008. These data and suggestions can provide transportation agencies and other stakeholders useful information for considering the adoption of standards. This would then allow transportation agencies or other organizations to clearly communicate internally and externally, including to the public and other stakeholders, what the animal detection systems can and cannot be expected to do. Depending on the results of the study mentioned above, additional research on minimum reliability norms may have to be conducted.

Recommendation 5: Conduct meta-analyses.
If reliable animal detection systems are installed along roads, researchers can measure the effectiveness of these systems in terms of fewer and less severe collisions with large mammals. While the existing research on the effectiveness of animal detection systems is encouraging, additional studies are needed before the estimates of collision reduction can be considered robust.

A major challenge is that the road sections over which animal detection systems are installed are often relatively short, usually only a couple of hundred yards (see *Huijser, et al. 2006*). The average number of large animals killed per time period prior to the installation of an animal detection system on those short road sections is usually relatively low. These numbers can vary substantially from year to year at a specific location due to chance alone. Combined with the fact that most projects only collect data from one location for a few years, it is potentially hard to show a statistically significant reduction in the number of animal-vehicle collisions after a system is installed and activated. Long road sections with animal detection systems at multiple locations and monitoring over many years can help resolve these issues.

Having a substantial number of road sections (e.g., between 5 and 10) where a reliable animal detection system has been installed and where the number of collisions is monitored is perhaps the most effective way to answer questions about system effectiveness. Multiple road sections with reliable animal detection systems directly increase the sample size. Pooling these data (i.e., conducting meta-analyses) would allow researchers to provide answers within a much shorter time period (e.g., 3-5 years). Note, however, that such meta-analyses could ignore potential differences between sites with regard to the detection technology used, potential differences in system reliability, potential differences in target species (e.g., deer, elk or moose), potential differences in the spatial arrangement of the sensors (e.g., systems deployed over long road sections vs. systems deployed at gaps in a fence), potential differences in warning signs, and potential differences in how drivers respond to warning signs.

Recommendation 6: Consider a BACI analysis.
Consider a BACI (Before-After-Control-Impact) analysis when measuring the effectiveness of animal detection systems in terms of fewer or less severe collisions. It is important that the data are collected in two ways: 1) for 3-5 years both before and after installation (comparison in time); and 2) at the site with the animal detection system and on road sections in the surrounding area (comparison in space). Comparisons in time may be confounded by fluctuating animal populations, changes in traffic volume, the time of travel, and changes in the landscape that may influence animal movement patterns to and from the road. Comparisons in space may be influenced by differences in the landscape or any other types of differences between impact and control sites that could influence the likelihood of animal-vehicle collisions.

Recommendation 7: Keep search and reporting efforts for crashes and carcasses constant.
Monitoring the number of animal-vehicle collisions or the number of animal carcasses along a road does not necessarily mean that every collision or carcass must be reported; but it does require a fixed search and reporting effort. Incidental observations or inconsistent search and reporting efforts result in data that are not suitable to investigate the most important measures of system effectiveness: the number of animal-vehicle collisions or the number of animals killed by vehicles.

Recommendation 8: Investigate the mechanism behind system effectiveness.
Fewer and less severe collisions can be obtained through lower vehicle speed, increased driver alertness, or a combination of the two. To illustrate how increased driver alertness can result in fewer and less severe collisions, consider the following calculation. Driver reaction time to an unusual and unexpected event can be reduced from 1.5 seconds to 0.7 seconds if drivers are warned (*Green 2000*). Assuming a constant vehicle speed of 55 mi/h (88 km/h) before and after the warning signals are presented to the driver, increased driver alertness could reduce the stopping distance of the vehicle by 68 ft (21 m). This reduction in reaction time and stopping distance, however, has not specifically been tested with respect to the presence of large animals in rural areas.

The awareness and alertness of the driver is likely to be influenced by the type of warning signals presented. Currently there are no specific standards for these warning signals and signs; and regulations and practices differ between countries and different regions within a country. There is evidence, however, that different signs are interpreted differently by drivers. If drivers are presented with a non-activated warning light and a standard black on yellow deer warning sign, accompanied by a black on yellow warning text sign saying “Use extra caution when flashing,” 92% of the respondents interpret the sign correctly, i.e., that there may still be deer on the road despite the fact that the warning signals are not activated (*Katz, et al. 2003*). This percentage is much lower when another message is used: “Animal detected when flashing” (57.6%); and “When flashing” (62.5%).

Drivers may not increase their eye movements (scanning behavior) in response to activated warning signs (*Hammond and Wade 2004*). The presence of deer or a deer decoy in the right-of-way does seem to trigger a relatively strong reduction in vehicle speed when the flashing warning lights are activated (*Gordon, et al. 2001*; *Gordon and Anderson 2002*; *Kinley, et al. 2003*; *Gordon, et al. 2004*). This indicates that activated warning signals may indeed cause drivers to be more alert.

In addition, including advisory or mandatory speed limit reductions with the warning signs may increase the effectiveness of warning signs. Furthermore, the appropriate distance between warning signs should be investigated. Rather than installing a warning signs at certain rigid intervals (e.g., ½ mi), it appears that drivers should not be allowed to pass a warning sign before they can see and interpret the next warning sign. Since these warning signs are dynamic, they do not have to show any information (e.g., an unlit LED panel) unless an animal has been detected, thus preventing overexposing drivers to warning signs. These types of research questions can be best addressed using a driving simulator (see e.g., Hammond and Wade 2004). In this controlled setting humans can be exposed to a virtual road environment with different warning signs and different types of wildlife observations (e.g., allowing for longer or shorter reaction times before the (virtual) vehicle would hit the (virtual) animal). Driving simulators also allow for detailed measurements of driver response (e.g., reaction time, eye movements, braking, stopping distance, and speed on impact).

Recommendation 9: Investigate system reliability along the roadside.
More intensive investigation of the reliability of an animal detection system along a roadside environment can include using sand beds, snow, or infrared cameras for the tracking of animal movements in the detection zones of the system, along with incidental observations by personnel or the general public of animal movements. Such data on animal movements may be combined with detection data that may be saved by a system, including a date and time stamp and the detection zone in which the observation occurred. (See *Huijser, et al. 2006* for a more detailed description of these methods.)

Recommendation 10: Investigate the effect of the system and activated signs on speed on-site.
It is advisable to measure vehicle speed before and after an animal detection system is installed, both in the road section with the system and at control sites. Data should also be collected within the animal detection area both with and without activated warning signs. Depending on the type of traffic counters used, one may be able to follow individual vehicles as they approach, travel through, and leave the road section with the animal detection system. Ideally, road and weather conditions should also be recorded, as driver response may be dependent on them as well. Small differences in speed are harder to reliably measure than large differences in speed. Speed differences smaller than 3 mi/h (5 km/h) can require a sample size of many hundreds of vehicles per treatment. Speed differences greater than 3 mi/h (5 km/h) can be reliably measured with much smaller sample sizes.

Another consideration in sample size is distinguishing between different types of vehicles. For example, drivers of semi-trucks may respond differently to activated warning signs than drivers of smaller vehicles, e.g., a passenger car or a motorcycle. Differentiating among multiple vehicle types necessitates a larger sample size.

Yet another consideration is that vehicles that travel close together (in a platoon) do not have speeds that are independent from each other. To minimize such dependence in the data, the authors recommend only including the speed of the lead vehicle in the data analyses and applying a minimum gap between vehicles (e.g., 10 seconds) before using the speed of the next vehicle.

The question that is likely to be of most interest is whether drivers reduce the speed of their vehicles in response to the activated warning signs, and by how much. The most straightforward design of such a study would consist of comparing vehicle speeds with the warning signs off versus warning signs on. If an animal detection system is operating reliably, the warning signs may not be on very often, and perhaps mostly under certain conditions (e.g., dawn or dusk). Therefore the authors recommend having the option to manually "force" the warning signs on during certain times. The authors do not recommend forcing the warning signs off though. Instead the authors recommend screening the detection log of the system for time periods when the warning signs were off. This way the animal detection systems are never switched off, and the study design does not expose travelers to potential false negatives.

Researchers may consider including a range of road and weather conditions in their study design, including day/night, dry/slippery road surface, dry weather/precipitation, etc., as drivers appear more likely to reduce their speeds when visibility and road and weather conditions are poor.

Researchers may consider measuring vehicle speed at one or multiple locations. If one location is chosen, then the location should be within the area equipped with the animal detection system and the warning signs. If multiple locations are an option, the researchers may be able to detect changes in vehicle speeds as drivers approach the area with the animal detection system, are exposed to the warning signs with or without activation, and then leave the road section with the animal detection system. Ideally, speed changes can be related to individual vehicles, allowing researchers to match speed measurements at different locations for the same vehicle, reducing variability in the data.

Vehicle speed can be measured in multiple ways. See Huijser, et al. (*2006*) for a discussion on the pros and cons of the use of traffic counters with tubes across the road, radar guns, and stopwatches.

Recommendation 11: Investigate the effect of the system and activated signs on driver response on-site.
Speed radar in combination with infrared cameras that continuously track vehicles as they approach, travel through, and leave the road section with an animal detection system may be used to measure driver response and potentially driver reaction time. In this case, driver response can be a combination of changes in vehicle speed, stopping distance, and potential lane or road departures.

7.4 CONCLUSION

While animal detection systems should still be characterized as experimental, the results of Phase II of this project are encouraging and suggest that animal detection systems can be effective in reducing collisions with large mammals. Nonetheless, additional research is needed, especially with regard to the effectiveness of animal detection systems in reducing collisions with large mammals, as the current data are not robust.

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APPENDICES

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APPENDIX B: VEHICLE TYPES DISTINGUISHED BY THE TRAFFIC COUNTERS

FHWA Type F Vehicle Classification Scheme

Class 1 – <u>Motorcycles.</u> This class includes all two- or three-wheeled motorized vehicles. These vehicles typically have a saddle-type of seat and are steered by handlebars rather than a steering wheel. This includes motorcycles, motor scooter, mopeds, motor-powered bicycles and three-wheel motorcycles.
Class 2 – <u>Passenger cars.</u> This class includes all sedans, coupes and station wagons manufactured primarily for the purpose of carrying passengers, including those pulling recreational or other light trailers.
Class 3 – <u>Pickups, Vans, and other 2-axle, 4-tire single unit vehicles.</u> This class includes all two-axle, four tire vehicles other than passenger cars, which includes pick-ups, vans, campers, small motor homes, ambulances, minibuses and carryalls. These types of vehicles that are pulling recreational or other light trailers are included.
Class 4 – <u>Buses.</u> This class includes all vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This includes only traditional buses, including school and transit buses, functioning as passenger-carrying vehicles. All two-axle, four tire minibuses should be classified as Class 3. Modified buses should be considered to be trucks and classified appropriately.
Class 5 – <u>Two-Axle, Six-Tire Single Unit Trucks.</u> This class includes all vehicles on a *single frame* that have *two axles and dual rear tires*. This includes trucks, camping and recreation vehicles, motor homes, etc.
Class 6 – <u>Three-Axle Single Unit Trucks.</u> This class includes all vehicles on a *single frame* that have *three axles*. This includes trucks, camping and recreation vehicles, motor homes, etc.
Class 7 – <u>Four or More Axle Single Unit Trucks.</u> This class includes all vehicles on a *single frame* with *four or more axles*.
Class 8 – <u>Four or Less Axle Single Trailer Trucks.</u> This class includes all vehicles with *four or less axles* consisting of *two units*, in which the pulling unit is a tractor or single unit truck.
Class 9 – <u>Five-Axle Single Trailer Trucks.</u> This class includes all *five-axle* vehicles consisting of *two units* in which the pulling unit is a tractor or single unit truck.
Class 10 – <u>Six or More Axle Single Trailer Trucks.</u> This class includes all vehicles with *six or more axles* consisting of *two units* in which the pulling unit is a tractor or since unit truck.
Class 11 – <u>Five or Less Axle Multi-Trailer Trucks.</u> This class includes all vehicles with *five or less axles* consisting of *three or more units* in which the pulling unit is a tractor or single unit truck.
Class 12 – <u>Six-Axle Multi-Trailer Trucks.</u> This class includes all *six-axle* vehicles consisting of *three or more units* in which the pulling unit is a tractor or single unit truck.
Class 13 – <u>Seven or More Axle Multi-Trailer Trucks.</u> This class includes all vehicles with *seven or more axles* consisting of *three or more units* in which the pulling unit is a tractor or single unit truck.

APPENDIX C: SURVEY FOR THE TRAVELING PUBLIC

SURVEY

EXPERIENCES WITH AND OPINIONS ON THE ANIMAL DETECTION SYSTEM ALONG US HWY 191 IN YELLOWSTONE NATIONAL PARK

Background information

In the fall of 2002 an animal detection system was installed along US Hwy 191 in Yellowstone National Park (at mile marker 28-29) between West Yellowstone and Big Sky, MT) (Photo 1). This survey attempts to investigate driver's experiences with and opinions on this system.

Photo 1. The animal detection system along US Hwy 191 in Yellowstone National Park (at mile marker 28-29) between West Yellowstone and Big Sky, MT (Photo: Marcel Huijser).

This is a voluntary and anonymous survey

This survey is intended for people 18 years of age or older. It will take approximately 5-10 minutes and is anonymous. Your responses will not be linked to you in any manner. Your participation is entirely voluntary. You do not have to take this survey if you prefer not to. If you have any questions about this survey, please contact:

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Instructions

Please select one answer per question unless the instructions say otherwise. If the options do not match your situation exactly, please select the answer that best describes your situation. If you cannot answer a certain question, or if you do not want to answer a certain question, please skip it and move on to the next question.

SECTION 1

1. What is your age?

18-24 years

25-44 years

45-64 years

65-85 years

86 years or over

I do not wish to answer this question

2. Are you male or female?

Male

Female

I do not wish to answer this question

3. When traveling in rural areas in the northwestern United States, how frequently do you worry about hitting animals from the following species groups? Please use a five-point scale where 1 means you **never** worry about it, 5 means that you **always** worry about it, and 3 means you sometimes worry about it. **(Select one number per species group)**

Domestic pets, such as cats and dogs 1 2 3 4 5

Farm animals, such as cattle, horses, or llamas 1 2 3 4 5

Medium-sized wild mammals, such as skunk, raccoon, or coyote 1 2 3 4 5

Large-sized carnivores, such as bear, wolf, mountain lion 1 2 3 4 5

Large hoofed mammals, such as deer, elk, or moose 1 2 3 4 5

4. How often do you typically travel on US Hwy 191 between Big Sky and West Yellowstone?

Never (please proceed to SECTION 4, question 18)

Once a year or less

2-12 times a year

2-4 times per month

2 or more times a week

I do not wish to answer this question

5. What vehicle type do you typically use when traveling this road section?

Motorcycle

Passenger car, minivan (with or without trailer)

Pick-up, SUV, van (with or without trailer)

Small truck, bus or RV (2 axles; without trailer)

Large truck, bus or RV (3 or more axles; with or without trailer)

I do not wish to answer this question

6. When was the most recent time you traveled travel on US Hwy 191 between Big Sky and West Yellowstone?

Within the last 30 days

Within the last 2 months

Within the last 6 months

In 2007 or later, but more than 6 months ago

In 2006 or earlier (please proceed with SECTION 4, question 18)

I do not remember (please proceed with SECTION 4, question 18)

SECTION 2

7. Have you noticed the animal detection system and/or the accompanying warning signs?

Yes

No (please proceed with SECTION 4, question 18)

I do not remember (please proceed with SECTION 4, question 18)

8. What do you think the message is when the warning signs are flashing (= activated) (see photo of sign)?

Animals often cross the road in this area

Animals may be present on or near the road

Animals are present on or near the road

I do not understand the warning message

Other   Please describe

9. What do you think the message is when the warning signs are NOT flashing (= NOT activated) (see photo of sign)?

There is no message

Animals often cross the road in this area

Animals may still be present on or near the road

Animals are NOT present on or near the road

I do not understand the message

Other   Please describe

10. Would you like to see the animal detection system along US Hwy 191 removed or stay in place?

Remove the system Please describe why

Have the system stay in place   Please describe why

No preference

11. Did you observe wildlife on or close to the road in the road section with the system in 2007 or later?

Yes

No (please proceed with SECTION 4, question 18)

I do not remember (please proceed with SECTION 4, question 18)

SECTION 3

12. What species did you observe along the road section with the system? If you observed wildlife on multiple occasions, or if you observed multiple species, please report on the "**most memorable**" event.

Elk

Mule deer

Moose

Black bear

Grizzly bear

Coyote

Wolf

Other Please describe

I do not know

13. Was one or more of the amber warning lights on top of the sign flashing (=activated)?

Yes

No

I do not remember

14. Were you the driver or a passenger?

Driver

Passenger (please proceed with question 16)

15. If the warning lights were flashing (=activated), how did you respond to seeing the activated warning signals? (Please check all that apply.) If the warning lights were not flashing, please proceed with question 16.

I reduced my speed

I became more attentive and looked for animals

I responded in another way Please describe how

I did not respond

I do not remember

16. Do you feel the animal detection system was helpful in this situation?

Yes Please describe why

No Please describe why not

I do not know

17. If you want to, you can use the space below to further describe your experience with wildlife on or close to the road in the area with the animal detection system.

SECTION 4

18. Do you think animal detection systems are a good idea? This question relates to animal detection systems in general, not the one along US Hwy 191 in specific.

Yes Please describe why

No Please describe why not

I do not know

19. Animal detection systems are designed to warn you when animals are on or near the roadway. For you to be confident in such a system, what percentage of large animals (deer and larger) that approach the road do you think should be detected by an animal detection system?

60% or less

61-70%

71-80%

81-85%

86-90%

91-95%

96-99%

100% (all large animals that approach the road are detected)

I do not know

20. Certain weather conditions, low flying birds, falling leaves or high vegetation can result in a "detection" and the activation of the warning signs. What percentage of the total number of detections would you allow to be "false" (that is, the warning lights are on, but there is not really a large animal present)?

41% or more

31-40%

21-30%

11-20%

6-10%

1-5%

0% (the warning signs are only activated when a large animal is really there)

I do not know

21. What percentage reduction in collisions with large wildlife (deer and larger) would you want to see or expect to see as a result of the presence of an animal detection system?

60% or less

61-70%

71-80%

81-85%

86-90%

91-95%

96-99%

100% (all wildlife-vehicle collisions are prevented)

I do not know

22. Animal detection systems cost money, but they can also save money through preventing collisions. In your opinion, what should be the balance between the cost and benefits of animal detection systems?

The systems must save money to society

The systems must at least save as much money as they cost to society

The systems are allowed to cost (some) money to society

I do not know

23. Please rank the importance of potential improvements of animal detection systems. Use a five-point scale where 1 means it is **not important** and 5 means that it is **very important**. **(Circle one number per question)**

Reliable systems 1 2 3 4 5

Clear, easy to understand warning signals 1 2 3 4 5

Small, unobtrusive systems 1 2 3 4 5

Inexpensive systems 1 2 3 4 5

Other (Please describe) 1 2 3 4 5

24. If you have any comments or thoughts related to the animal detection system along Hwy 191 or animal detection systems in general, please use the space below:

Many thanks for filling out this survey, we appreciate it!

Should you have further questions about this survey, please contact:

Marcel P. Huijser, PhD, Research Ecologist, Road Ecology Program
Western Transportation Institute, Montana State University (WTI-MSU)
PO Box 174250, Bozeman MT 59717-4250
Phone: 406-543-2377, E-mail: mhuijser@coe.montana.edu
http://www.coe.montana.edu/wti/road_ecology.html

Further information about animal detection systems

Animal detection systems use high-tech equipment to detect large animals (e.g. deer size and larger) as they approach or cross the road. Once a large animal is detected, warning signs are activated that aim to make the driver pay more attention, reduce vehicle speed, or both. This should then lead to fewer or less severe collisions, reducing property damage and improving safety for humans. In addition, wildlife road mortality is reduced while not blocking animal movements across the road.

In the fall of 2002 an animal detection system was installed along US Hwy 191 in Yellowstone National Park (mile marker 28-29) between West Yellowstone and Big Sky, MT). Prior to the installation of the system, an average of 5.6 elk per year were hit along this road section. After several years of testing and modifications, the system was put in full operation on 18 January 2007.

If you are interested in learning more about animal detection systems, you can download a research report on animal detection systems from the internet:

Huijser, M.P., P.T. McGowen, W. Camel, A. Hardy, P. Wright, A.P. Clevenger, L. Salsman & T. Wilson. 2006. Animal Vehicle Crash Mitigation Using Advanced Technology. Phase I: Review, Design and Implementation. SPR 3(076). FHWA-OR-TPF-07-01, Western Transportation Institute – Montana State University, Bozeman, MT, USA. Available from the internet: http://www.oregon.gov/ODOT/TD/TP_RES/ResearchReports.shtml

APPENDIX D: RESULTS OF SURVEY FOR THE TRAVELING PUBLIC

Results of Survey for the Traveling Public

Each question posed in the survey is provided below followed by a graph summarizing the responses.

1. What is your age?

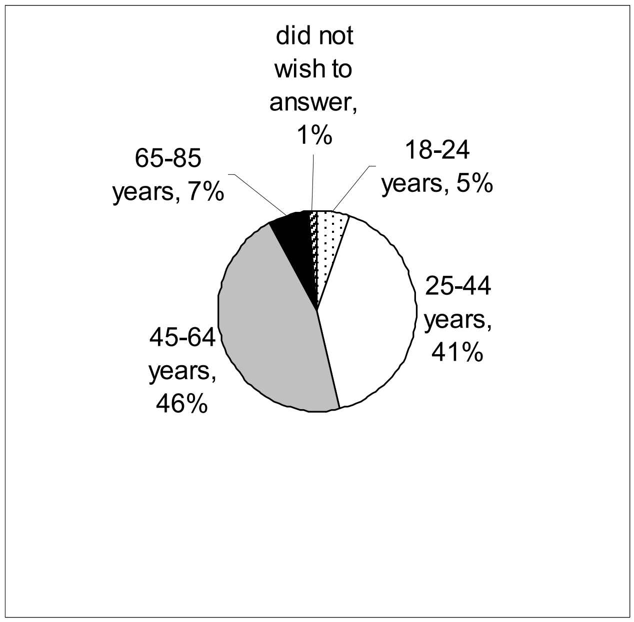

Figure D.1: Age distribution of the respondents (N=151)

2. Are you male or female?

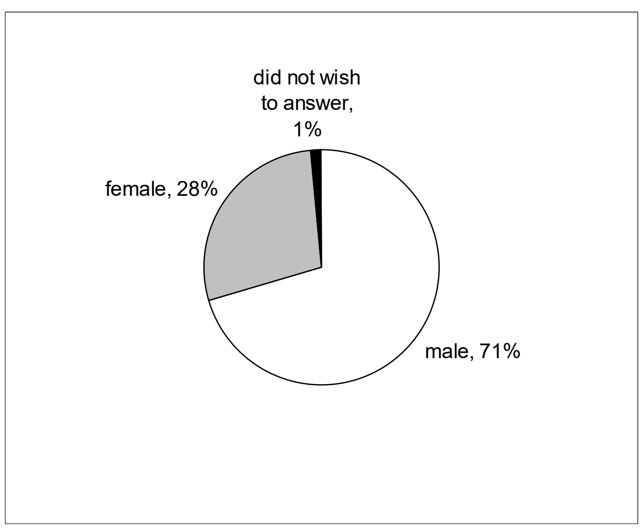

Figure D.2: Gender distribution of the respondents (N=151)

3. When traveling in rural areas in the northwestern United States, how frequently do you worry about hitting animals from the following species groups? Please use a five-point scale where 1 means you **never** worry about it, 5 means that you **always** worry about it, and 3 means you sometimes worry about it. **(Select one number per species group).**

   a. Domestic pets, such as cats or dogs

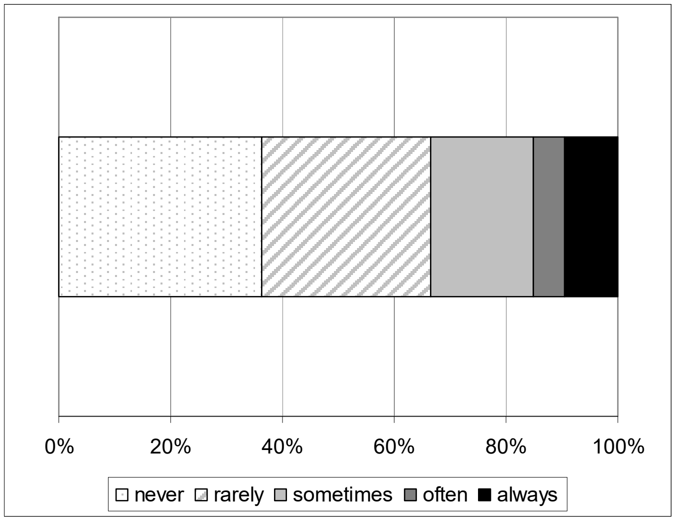

Figure D.3: Concern respondents have about collisions with domestic pets (e.g. cats, dogs) (N=146)

   b. Farm animals, such as cattle, horses, or llamas

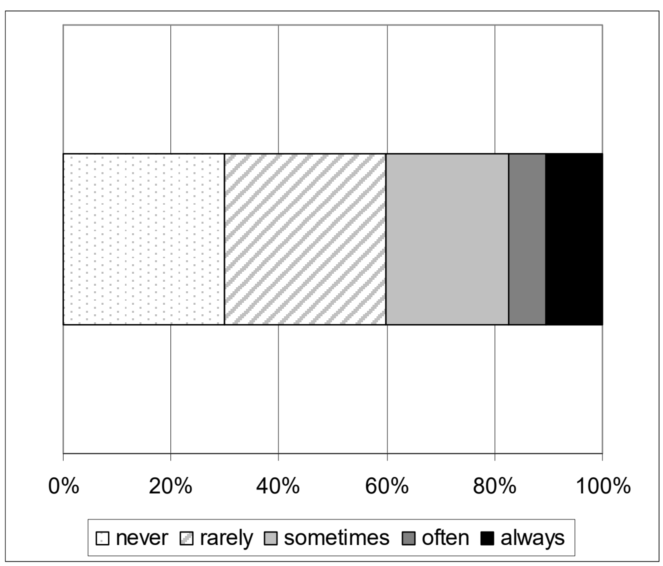

Figure D.4: Concern respondents have about collisions with farm animals (e.g. cattle, horses, or llamas) (N=144)

c. Medium-sized wild mammals, such as skunk, raccoon, or coyote

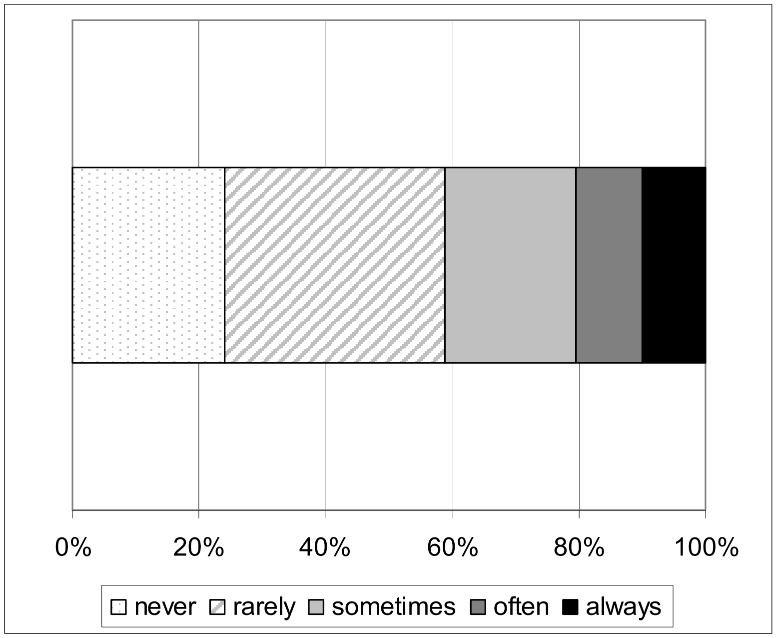

Figure D.5: Concern respondents have about collisions with farm animals (e.g. cattle, horses, or llamas) (N=144)

d. Large-sized carnivores, such as bear, wolf, mountain lion

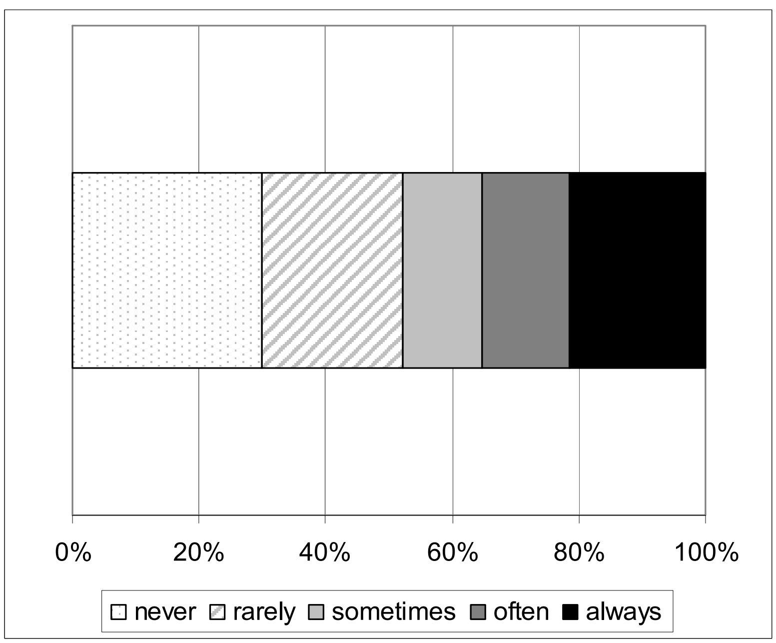

Figure D.6: Concern respondents have about collisions with large-sized carnivores (e.g. bear, wolf, mountain lion) (N=144)

e. Large hoofed mammals, such as deer, elk, or moose

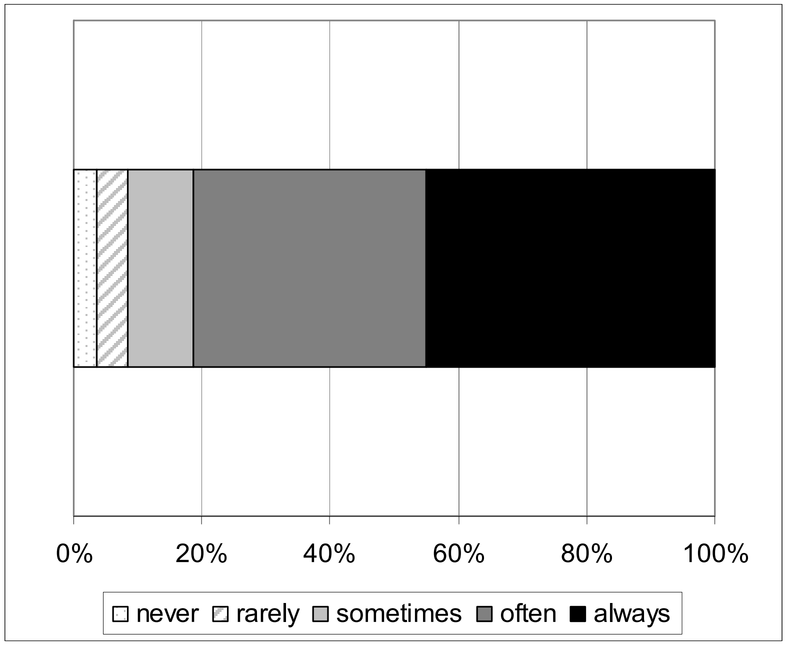

Figure D.7: Concern respondents have about collisions with large hoofed mammals (e.g. deer, elk, or moose) (N=144)

4. How often do you typically travel on US Hwy 191 between Big Sky and West Yellowstone?

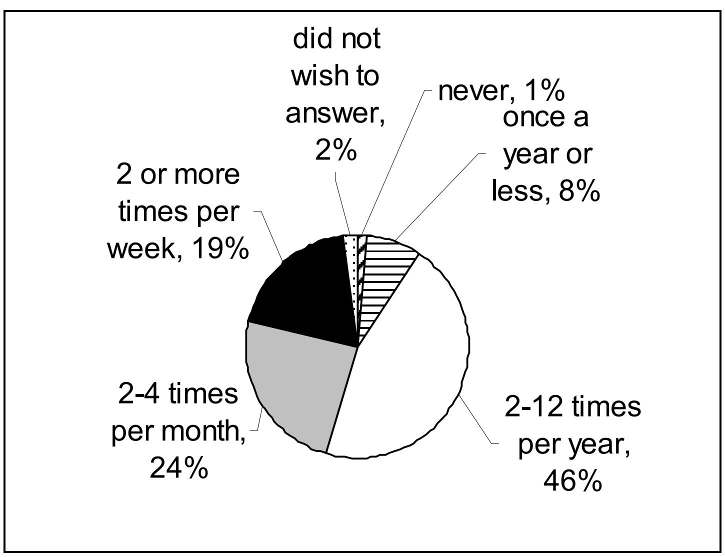

Figure D.8: Travel frequency on US Hwy 191 between Big Sky and West Yellowstone (N=149)

5. What vehicle type do you typically use when traveling this road section?

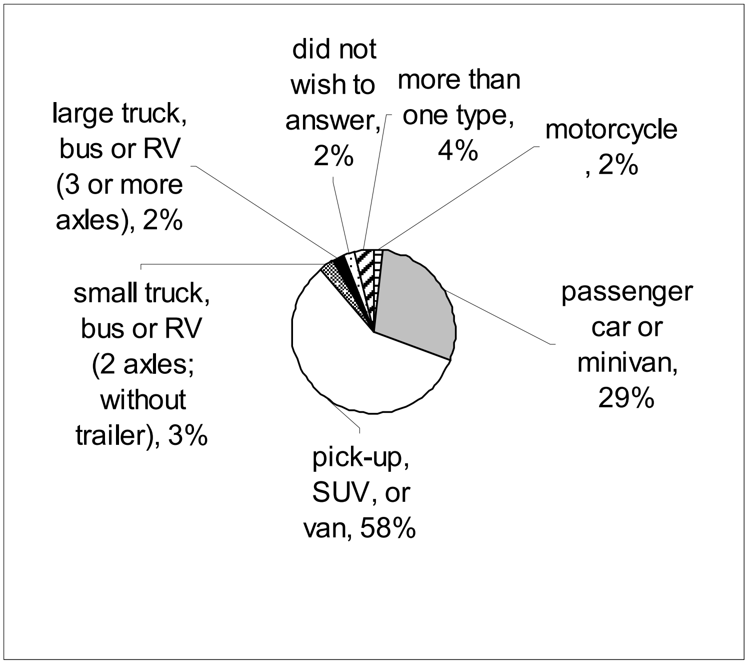

Figure D.9: Vehicle type used by respondents when traveling on US Hwy 191 between Big Sky and West Yellowstone (N=149)

6. When was the most recent time you traveled on US Hwy 191 between Big Sky and West Yellowstone?

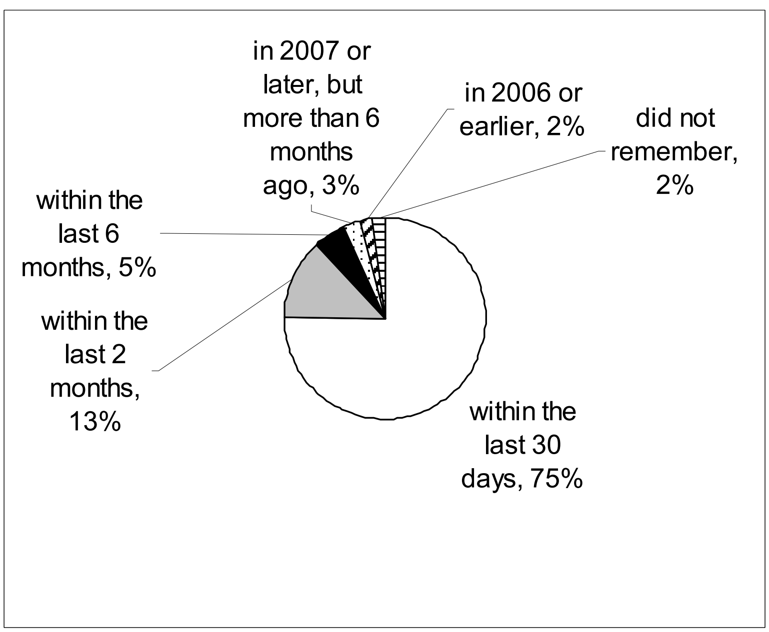

Figure D.10: Most recent time respondents traveled on US Hwy 191 between Big Sky and West Yellowstone (N=149)

7. Have you noticed the animal detection system and/or the accompanying warning signs?

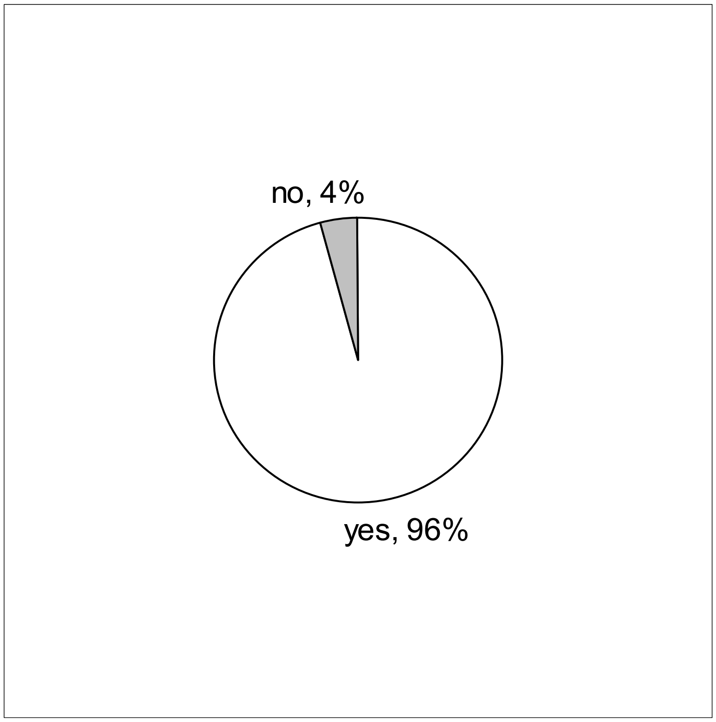

Figure D.11: Respondents that noticed the animal detection system and accompanying warning signs (N=145)

8. What do you think the message is when the warning signs are flashing (= activated)?

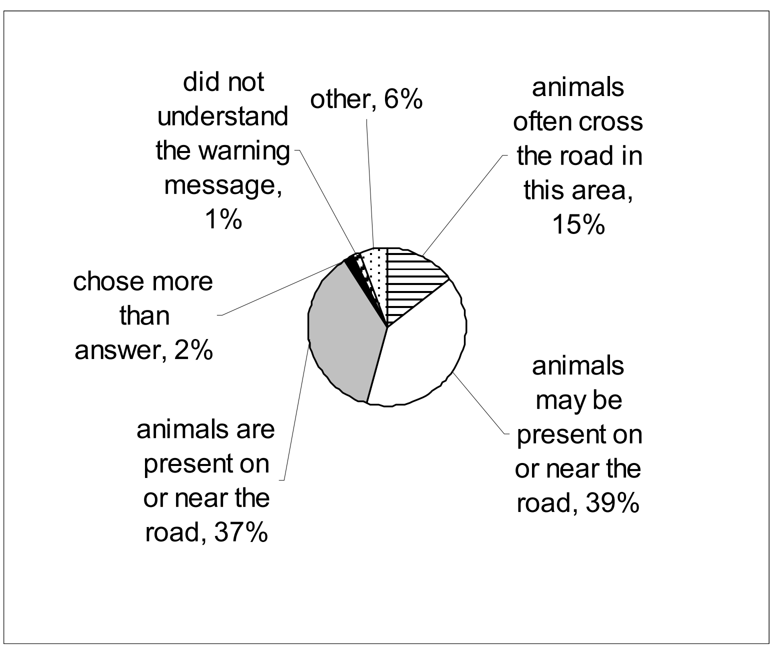

Figure D.12: Respondents' interpretations of activated warning signs (N=142)

The activated warning signs were correctly interpreted by 39% of the respondents. Note that the warning signs may have also been activated by something else besides large mammals, and that activated warning signs do not necessarily mean that there are large animals on or near the road. However, 91% of the respondents were apparently aware that large animals may be on or near the road in this area.

Eight respondents offered other message interpretations along the following lines (some spelling errors were corrected to enhance readability):

<u>The system is not working.</u>
1) "It is not working again like 12:55 9/30/07."
2) "I assume the system is not working, again."

<u>The system has been triggered.</u>
1) "Something has triggered the system (wind, people, animals)."
2) "A car has passed recently."
3) "Both, kind of mean the same, if animal is crossing then they should be on or near road."
4) "Never seen it in operation, if I did I would assume animals on by roadway."
5) "I've never seen the signs flashing, but I have watched many animals cross in the area." (This respondent did not make a selection but offered this statement and is counted as "other.")

<u>Slow down.</u>
1) "It's a warning, slow down."

9. What do you think the message is when the warning signs are NOT flashing (=NOT activated)?

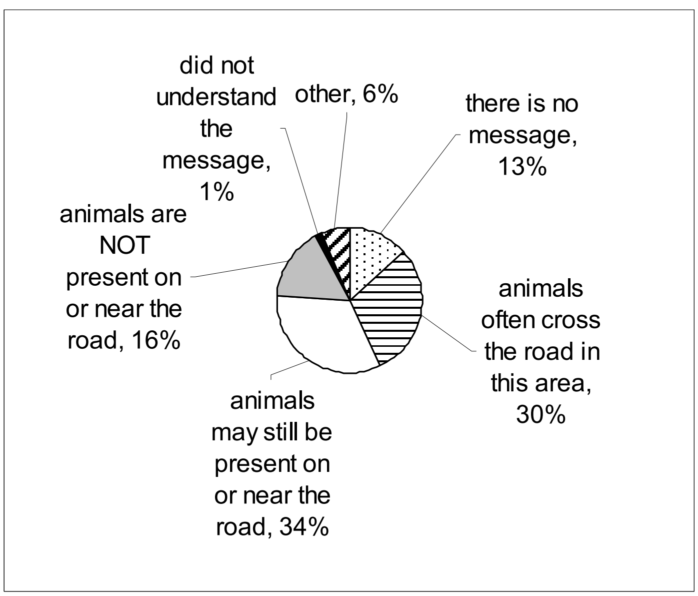

Figure D.13: Respondents' interpretations of non-activated warning signs (N=142)

The non-activated warning signs were correctly interpreted by 64% of the respondents. While the warning signs may not be on, large animals can still be on or close to the road. At the same time 17% of the respondents thought that there were no animals present on or near the road or did not understand the message.

Seven respondents offered other message interpretations along the following lines (some spelling errors were corrected to enhance readability):

<u>The system is not working.</u>

1) "Seems to always be flashing."
2) "It is out of order again."
3) "System may or may not be operating."
4) "I still think the system is not working."

<u>The system has not been triggered.</u>

1) "No animals have triggered the beam."
2) "The beams have not been broken in the last 10 minutes or so."

<u>Be alert.</u>

1) "Be alert."

Two respondents offered comments in response to this question.

1) "We always drive that area with a heightened sense of awareness."
2) "Both, kind of mean the same, if animal is crossing then they should be on or near road."

10. Would you like to see the animal detection system along US Hwy 191 removed or stay in place?

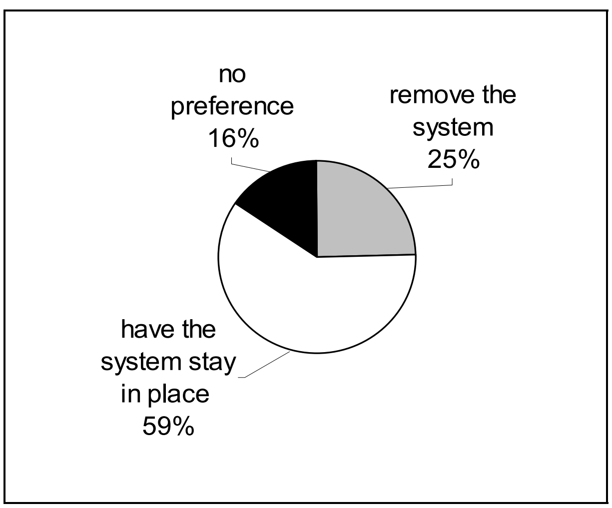

Figure D.14: Respondents' wishes with regard to the animal detection system along US Hwy 191 in Yellowstone National Park (N=141)

Some respondents who liked the system to stay in place gave reasons in the following categories (some spelling errors were corrected to enhance readability):

Perceived value

1) "I think it is valuable, however, more additional info is needed, such as, 'proceed with caution when flashing' or 'flashing indicates wildlife within 50 yards of the roadway' or something."
2) "It increases motorist safety and protects wildlife."
3) "Good idea and may decrease chances of hitting an animal."
4) "I would prefer seeing detection systems like this rather than road-killed animals on the highway shoulders!"
5) "It makes me feel safer as a driver. If the light is flashing I am extra cautious and adjust my speed accordingly. Particularly helpful at dusk/dawn."
6) "Safety for all road users involved!"
7) "It's painfully obvious, but I'll describe why anyway; It's nice to know how high the probability of hitting a large animal is."
8) "I see lots of animals (elk, mostly) in this area. While I may be 'a local' and alert, not everyone is. Visitors to the area really don't appreciate how prevalent the animals are."
9) "It would be very helpful at night when visibility is low and would also be good for people not familiar with the road and wildlife on the road."
10) "A visible reminder to motorists to be extra alert in this area. Collisions with wildlife can cause loss of life, both to the traveling public and wildlife."
11) "It is one more safeguard in the possible prevention of killing an animal, injuring oneself and passenger, damaging my vehicle, etc."
12) "Enough animals are killed by hunters."
13) "I think it's important to monitor because you can determine increase/decrease in population in the area and determine how many animals cross in the area."
14) "Imperative for wildlife survival and stupid human behavior."
15) "It's a great idea. It should be put up in more places."
16) "Helpful regarding elk/deer crossing."
17) "Animal & human safety."
18) "Makes me aware of animal activity."
19) "It lets drivers know that animals are present."
20) "Less accidents=safer."
21) "For both human and animal safety."
22) "So I know that animals are more likely to be in the area when flashing."
23) "I think it is a great idea-I wish there were more of them."
24) "Works."
25) "Blind curves, warnings help-remind."
26) "Protect the animals and the people."

Support for maintaining until/provided proven effectiveness

1) "As long as it is working and effective."
2) "Please keep it in place until we know how well it works, and if it can be used elsewhere."

3) “Studying the habits of the animals when we are 'in their way' is always good. If this type of system works, more of these types of warning systems could save lives in high traffic areas where animal patterns are consistent with high traffic areas.”
4) “Proof of concept. How many animals hit in 10 mile stretch of 191 compared to test strip.”
5) “IF it is effective!”
6) “If it works-yes.”
7) “Make it work, cost effective.”
8) “Animal movement for research, are they still here.”
9) “See if it is effective.”
10) “Good thing if it works.”
11) “If it protects animals keep it.”

Support for maintaining despite perceived inadequacies

1) “They should remain. However, I have noticed that they also warn when humans are walking near the road (like fishermen). No way to prevent this, however.”
2) “Animals become habituated to their surroundings and will cross irrespective of the warning signs so only by 'warning' motorists is there a chance to make them slow down and look. Most people drive with little regard for wildlife but any warning system that deviates their attention from otherwise 'oblivion' while driving has to be a positive - even if not the perfect answer.”
3) “I think it is a good idea, but honestly I haven't seen it flash more than maybe a time or two and there wasn't any elk in the area when it was flashing.”
4) “All steps must be taken to avoid hitting animals.”
5) “Maybe stay in place but I have never seen the warning signs activated or have I ever seen any animals in the area.”
6) “Even if it doesn't work it indicates to me that animals cross here.”
7) “Get it to work.”
8) “Can't hurt.”
9) “Can't hurt anything.”
10) “It's better than nothing.”

Removal not possible or keep (part of) system in place

1) “Too late now. But I fail to see the usefulness of it. Why not put a flashing light that stays on consistently warning of an always present danger.”
2) “It's already there.”

Some respondents who preferred removal of the animal detection system described their reasons in the following categories (some spelling and grammar errors were corrected to enhance readability):

Perceived ineffectiveness/trust issues/financial concerns

1) “It is now a 'cry wolf' for locals and a confusion to first timers. A “what is this thing”? It does not work properly based on the last two times I have seen it flashing. Once a fisherman was parked between the sensors and the other a WTI person was standing there

writing on a pad. A one sign system that is always flashing at the start of the N and S ends would do just as much without this sculpture of steel and glass."

2) "It never seems to be in working order."
3) "Because it isn't trustworthy, it has never worked, and what about the snow removal blocking the sensors. People need to PAY ATTENTION while driving, and quit having others think and do for them."
4) "The system just doesn't work effectively."
5) My spouse and I, frankly, feel the system has been a waste of time and money. We are seasoned travelers of that road summer and winter and have observed animals on the road when the lights are not flashing and the lights flashing when there isn't an animal in site anywhere! Once we even stopped and walked back and forth in front of the system with no response. I did observe it flashing once after a vehicle broke the beam driving into the Black Butte Ranch.
6) "Doesn't do anything."
7) "Waste of money."
8) "I have never seen the system work! And have been through it a lot."
9) "I think it is constantly going off without reason."
10) "Depends on cost; if maintaining the system long term is very costly then it should be removed."

<u>Aesthetic issues</u>

1) "Even when flashing, I've not seen the animals. It seems a bit of an eyesore for the little use I've seen it get."
2) "It's kind of an eyesore. I've only seen the lights activated once, during the day, and did not see any animals near or around the road. Never heard of anyone benefiting from the system."
3) "I don't like the way the system looks - there is too much 'stuff' there, along the road. I'd rather take my chances with the animals than see this large system alongside the road."
4) "It is very ugly and destroys a very beautiful stretch of highway. People just need to exercise caution while traveling anywhere in this great state."
5) "It's an eyesore on a tiny stretch of road. Animals cross roads all over the place, so having this big, expensive system for a few hundred yards seems ridiculous."
6) "It is absolutely obnoxious. Of course there are animals on the roads in Yellowstone!"
7) "It is ugly and inappropriate for natural park environment. It would be better to have a single warning sign when entering the area and a reduced speed limit."
8) "It is an eye sore. It is a National Park and people should expect to see wildlife anywhere."
9) "A warning sign is fine but those things remind me of billboards. They definitely do not belong in the Park. You can only do so much for humanity to protect themselves from themselves."
10) "Just too much!"
11) "Eye sore."
12) "Unsightly, either remove or modify."

<u>Location concerns</u>

1) "Remove the system and put it where there are more animals (esp. elk) near the road."

2) “It is a waste; since the wolf reintroduction there have not been enough elk to justify it.”

<u>Combination of reasons</u>

1) “1-it is ugly, 2-it reads ANY moving object so drivers slow without reason, and local drivers ignore it. 3- it is unreliable. 4-it is a road hazard close to the highway for vehicles that go off the road for avoidance or by accident.”
2) “First, it is an eye-sore and a ridiculous waste of money. It gives the sense that the detection area is the only place that animals cross the road which couldn't be further from the truth. Traveling the road on a daily basis I see numerous places where animals are beside the road or crossing the road. I have yet to see an elk, deer or moose within the detection area even when the lights are flashing!”
3) “The system takes away from the natural beauty of the roadway and is not worth the cost of installation and maintenance.”
4) “It's unsightly and doesn't appear to work effectively.”
5) “It has not worked properly since it was put in. It is an eyesore. One mile out of the whole canyon is a waste of time.”
6) “I don't think it works and that it is an eye sore. The decline in the elk in the Gallatin is substantially due to the wolf population.”
7) “This system has cost the taxpayers millions of dollars and doesn't work so get rid of it. It is ugly and shouldn't be in Yellowstone Park.”

One respondent who chose “no preference” commented “Doesn't seem accurate.”

11. Did you observe wildlife on or close to the road in the road section with the system in 2007 or later?

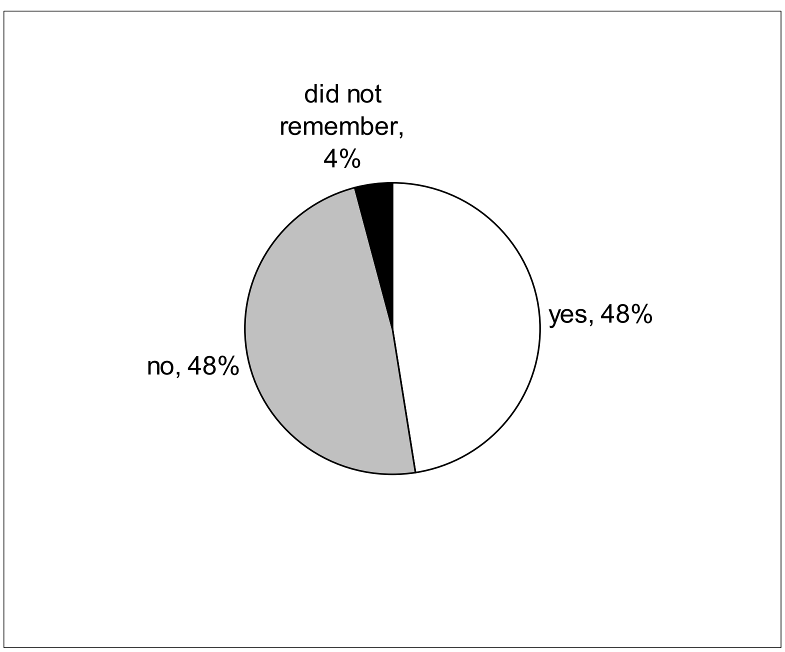

Figure D.15: Wildlife observations by the respondents in the road section with the system (N=141)

12. What species did you observe along the road section with the system? If you observed wildlife on multiple occasions, or if you observed multiple species, please report on the "most memorable" event.

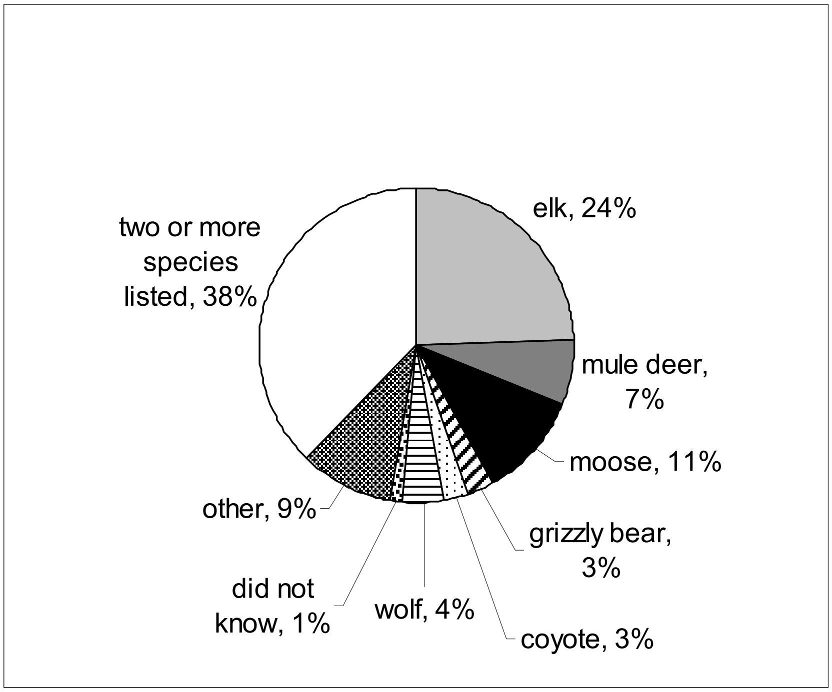

Figure D.16: Species observed by the respondents in the road section with the system (N=74)

Twenty-eight respondents indicated they have observed two or more species in the road section, all of which included at least one ungulate: elk, mule deer or moose. There is a discrepancy between the number of respondents who answered yes to Question 11 (n = 67) and the number of respondents who selected species which they have observed (n = 74). A possible reason for this is Question 12 did not explicitly request only wildlife observations made in 2007 or later.

13. Was one or more of the amber warning lights on top of the sign flashing (=activated)?

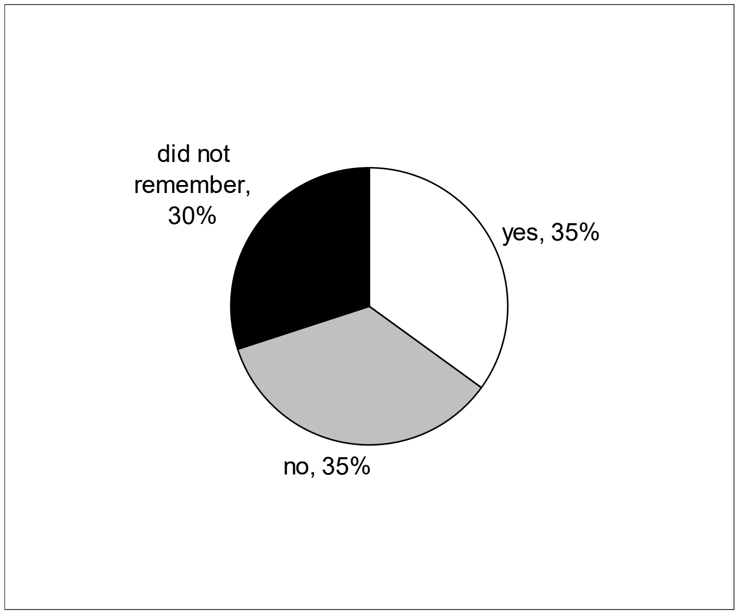

Figure D.17: Status of the warning signs (no=off; yes=on) as observed by the respondents (N=80)

One respondent who answered “no” clarified that the animal “was not in area with warning system.”

14. Were you the driver or a passenger?

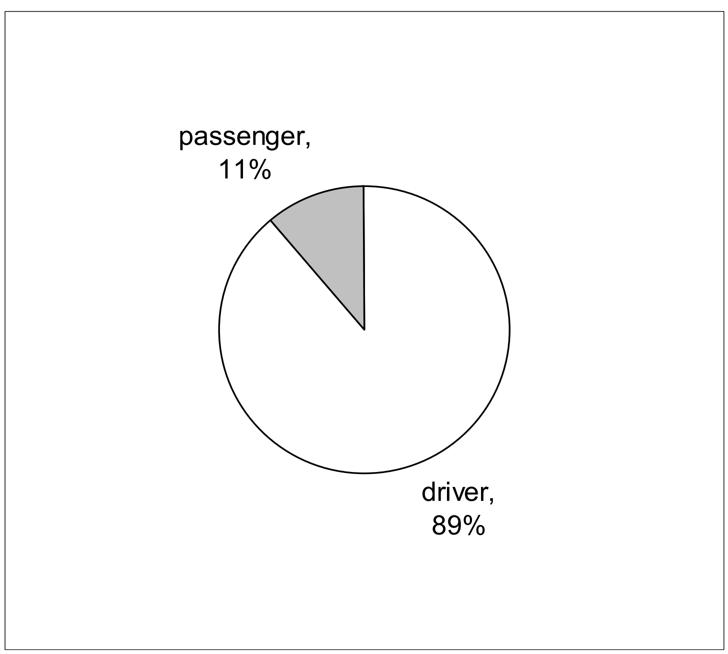

Figure D.18: Status of respondent in the vehicle (N=80)

15. If the warning lights were flashing (=activated), how did you respond to seeing the activated warning signals? (Please check all that apply.)

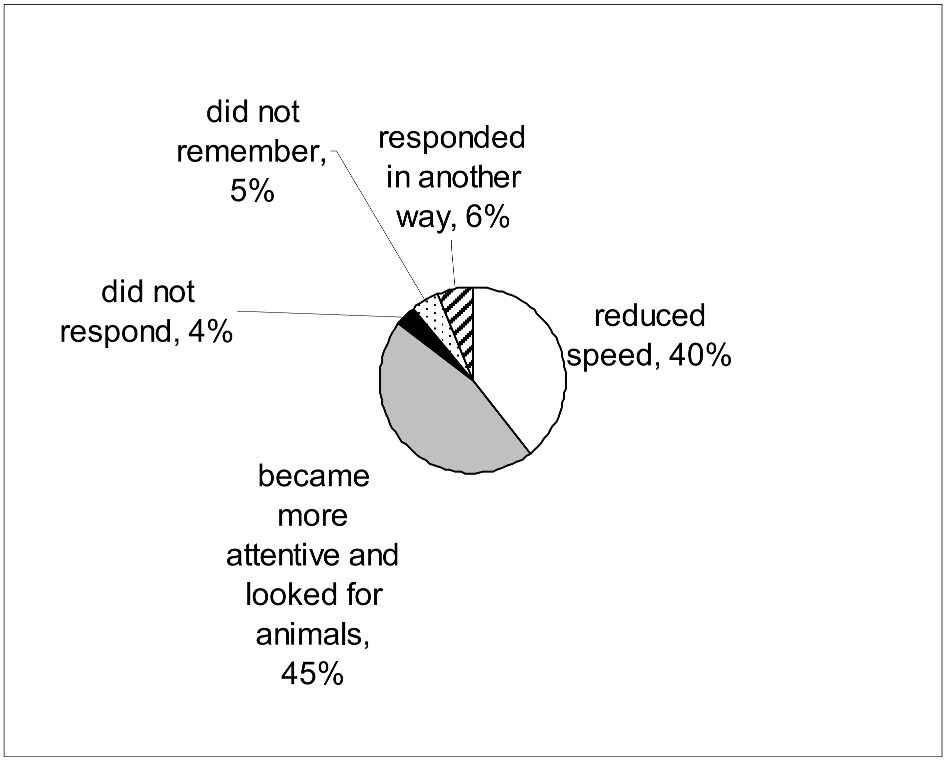

Figure D.19: Response to the activated warning signs (N=64)

Six percent indicated they responded in another way, some of whom offered comments, including:

1) "I continued to be aware of animals and go the speed limit."
2) "Wondered whether or not the system was actually working this time."
3) "Anger."

Four percent indicated they did not respond to an activated warning signal while 5% indicated they did not remember how they responded.

One respondent also offered the insight and suggestion, "We, as hikers crossing the road also tripped the blinking. Don't put them near a trail head."

16. Do you feel the animal detection system was helpful in this situation?

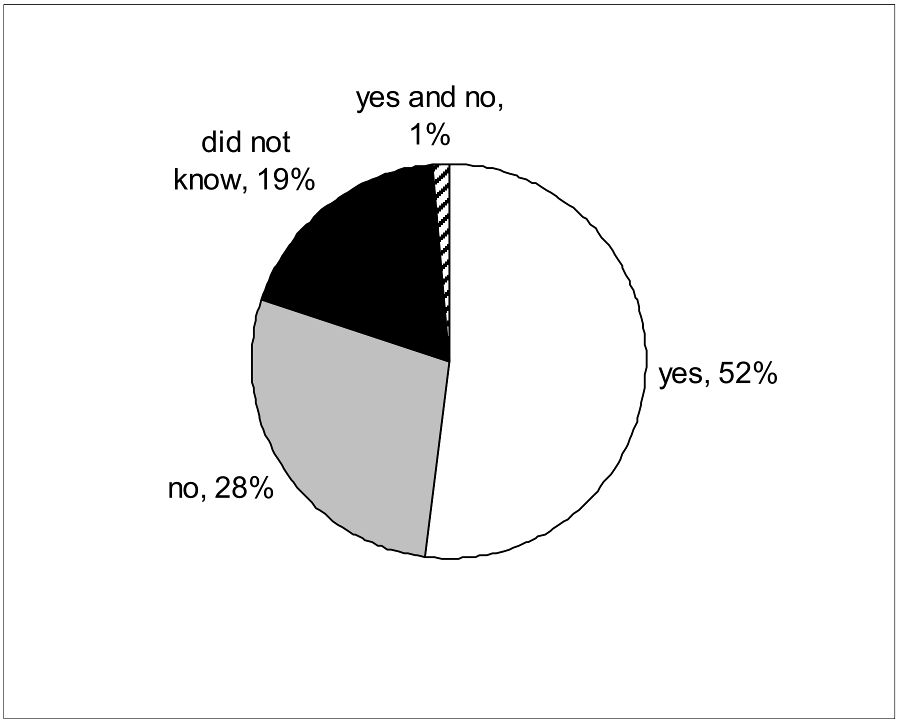

Figure D.20: Helpfulness of the system in that situation (N=75)

One respondent answered yes and no and gave the following rationale, "It becomes normal and you stop paying attention."

Some respondents who indicated they felt the system was helpful provided the following reasons (some spelling errors were corrected to enhance readability):

General

1) "Hitting a moose at night is easy, but also a potential disaster (for both me and the "moose)."
2) "Made me become more alert to watch for animals."
3) "Kept me alert."
4) "Caused me to be more attentive even though I was already going slower than the speed limit."
5) "The warning system signs reminded of the presence of animals in that section."
6) "I think people may slow down, people drive too fast through there."
7) "Cars are too fast (?) a moving object."
8) "It gave me a heads up."
9) "Slowed us down."
10) "It makes us stay heads up, but what an eyesore."
11) "Used more caution."
12) "Gets your attention."
13) "Paid closer attention."

14) “Alerts to animals you may not see.”
15) “I wasn't concerned about animals on the road.”
16) “Slower speeds mean stopping faster.”
17) “Warning sign that you wouldn't otherwise have-as animals appear so suddenly.”
18) “Yes. I slowed down even though animals weren't visible. May still have been present.”
19) “It made me pay more attention.”
20) “It let me know something was there.”
21) “Just a good warning.”

Specific

1) “It was dark out, snowy/icy road conditions, the lights were flashing, I slowed down, a 12 point bull elk was in the middle of the road and I avoided having to serve or brake hard to avoid a collision.”
2) “It was EXTREMELY helpful. Please keep it in place.”
3) “I wouldn't have known otherwise.”
4) “Lots of elk in that area.”
5) “I immediately saw a moose near the road.”

Some respondents who indicated they felt the system was not helpful provided reasons in the following categories (some spelling errors were corrected to enhance readability):

Perceived ineffectiveness/technical limitations

1) “The lights are on much more for vehicles than for animals or hikers crossing the road, so I no longer pay attention, without IR, or some other method of distinguishing between animals and vehicles this current system is ineffective.”
2) “Because one never knows whether the warnings are accurate or not.”
3) “Completely unreliable.”
4) “The system has flashed a few times and nothing was even close to the road and I have seen more animals near the road before and after the system.”
5) “If the idea is the animal is supposed to activate the light and it has crossed the road in that section and the light did not come on how effective is that?”
6) “Three times we had flashing light but did not see any animal near or on highway.”
7) “It didn't work.”
8) “It never worked.”
9) “Does not always work.”
10) “Did not see any animals in vicinity at all.”
11) “I don't think it works accurately.”

Disinterest/lack of reliance on the system

1) “I always try to be aware of my surroundings when traveling 191.”
2) “I'm always looking for animals there.”

Aesthetic concerns

1) “I was angered by the disruption of the scenic values by a flashing beacon. Aaaargh!!”

17. If you want to, you can use the space below to further describe your experience with wildlife on or close to the road in the area with the animal detection system.

Three respondents provided comments on their experiences.

1) "In the roadway with the detectors I only saw coyotes. I usually drive during the day. On the road to Bozeman I hit a deer."
2) "There is a fraction of the wildlife that used to be in that part of the canyon."
3) "I believe it does raise the attentiveness of responsible drivers. One additional key element is obeying the lower speed limit in the park."

18. Do you think animal detection systems are a good idea? This question relates to animal detection systems in general, not the one along US Hwy 191 in specific.

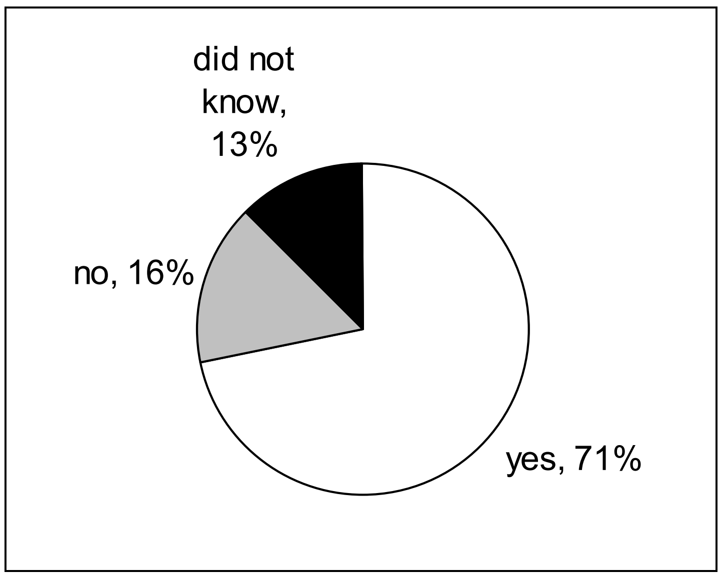

Figure D.21: Opinions of respondents on whether animal detection systems are a good idea (N=152)

Some respondents who indicated they think animal detection systems area good idea provided reasons in the following categories (some spelling and grammar errors were corrected to enhance readability):

<u>Safety/impact to wildlife</u>

1) "Seems like a no-brainer. Good for me in a vehicle, good for the wildlife ~ anything that can prevent a collision is a good idea."
2) "I travel a lot of long distances at night, and any help I can get to avoid potential accidents with animal encounters is very helpful. I think these systems should be put in place everywhere there is an abundance of animal crossings."
3) "Prevents animal and human injuries and death."
4) "They are a means to make highways safer for motorists and reduce wildlife mortalities (win-win)."
5) "Reduces crashes and can help to reduce fatalities of wildlife and people."

6) "Crashes with animals cause many injuries and huge amounts of monetary damages every year in many states. Anything to reduce this would be beneficial to all drivers."
7) "A far better view than road-killed animals. Knowing the cost (animal and human life, vehicle repair & insurance etc.) I think more of these should be used."
8) "Because going around that curve, knowing that there could be an animal on the road is a very good idea. In blind spots especially."
9) Helps reduce number of vehicle-wildlife collisions, keeping our wildlife numbers at healthy levels and making our roads safer."
10) "Safety for all road users!"
11) "We have encroached on traditional wildlife migratory paths and we should do all we can to help mitigate the injury and death we inflict on these animals. Also from an economic standpoint this is an opportunity for insurance companies and others to step up."
12) "Driving through that particular part of the park and knowing the amount of animal migration through that area, I would love to be alerted to animals that are crossing the roadway, especially if it is after dark."
13) "For the same obvious reasons I mentioned earlier."
14) "Any step taken that increases the awareness of animal behavior is desirable."
15) "Yes, I would like to see more of them even though I have never seen any animals near the test area."
16) "Increase alertness on the part of motorists."
17) "Generally I agree with the concept. Thousands of dollars are expended on vehicle damages and more importantly, lives are lost each year due to collisions with animals. This could help stop the loss of life and property damage if the system was functioning properly. Most of us who travel that road a lot do so with a heightened sense of awareness and preparation."
18) "Hopefully reduces the amount of wildlife killed and humans injured and property damaged."
19) "As I mentioned earlier, not only to study animal patterns, but to warn vehicles of animals crossing. It could be a perfect blend."
20) "Protect the animals from speeding cars."
21) "Because people are more aware and drive slower and more attentive."
    "Saves lives and reminds humans of responsibilities."
22) "Safer for drivers and animals."
23) "Keeps the highways more safe."
24) "Less car- animal collisions."
25) "I hate to hit animals."
26) "Further information regarding wildlife."
27) "If saves animals, lives, and vehicles."
28) "Generally we all drive too fast."
29) "I travel on Montana highways a lot and have hit deer and had many near misses."
30) "Warn drivers, slow down, especially at night."
31) "For animal and driver safety."
32) "As a warning and helps prevent accidents."
33) "Hit an elk with a car and you will know!"
34) "It reminds people that animals may be there."
35) "I love animals."

36) “Animal and human safety.”
37) “Protects animals.”
38) “Raise awareness.”
39) “Data gathering warning to vehicles.”
40) “Saves wildlife and human life, and vehicle damage.”
41) “Makes people use caution.”
42) “Gets your attention.”
43) “Research.”
44) “Because accidents happen a lot.”
45) “People don't always keep an eye open for wildlife.”
46) “Because that makes life safer for me, my passengers, and animals.”
47) “It gives me more confidence especially when driving in the evening and at dusk to alert drivers.”
48) “Less accidents=better!”
49) “Good all around for animals and us.”
50) “It could save a life.”
51) “Slows down traffic.”
52) “For safety of animals and vehicles.”
53) “The only time I have hit an animal was at high speeds.”
54) “So you're more aware that animals could be in the area and slow down.”
55) “Saves animals and accidents.”
56) “Early warning saves animal and damage to cars.”
57) “Works well.”
58) “They raise awareness.”
59) “Same as other question.”
60) “Today's cars are relaxing to drive and people are generally inattentive behind the wheel and in a hurry.”
61) “If it saves one.”
62) “Some info is better than none.”
63) “I have ruined five vehicles in the past five years because of animal collisions
64) “Anything to reduce road kill is good.”

<u>Support for idea with caveat</u>

1) “A single sign, with less obnoxious related hardware is a good idea. Figure out a way to hide the detection hardware.”
2) “In the right area. I never see animals in that area. I travel 191 often and almost never see animals in the day and evening. A good place to put one would be on US 89 in the Tom Miner area. Always see mule deer in that area even though I travel that…”
3) “If they worked, it would be a good warning sign for vehicles to be more cautious because animals are near or on the road.”
4) “If they work, yes. I still don't know if it really works. I have never seen wildlife on that actual section of road!”
5) “The individual detectors that you put on your car fall off, so this seems better. But one hopes that the animal isn't smarter than the device.”
6) “If they are in the right spot and are working properly, the detection system should prevent accidents.”

7) "Yes, but I thought this was a device to study, and not to warn motorists."
8) "Yes, if it helps to prevent accidents it is well worth it."
9) "But only if they work."
10) "ONLY if they are in a very specific, known crossing point where there have been problems in the past."
11) "If they worked and were not too obtrusive it would definitely make the roads safer."
12) "Helps protect individuals. Hard to make real time and believe light."
13) "If they work."
14) "If they can be adjusted to function properly."
15) "I think it has its place, but not here."
16) "If it is cost effective."
17) "For some animals, preferably mule deer and elk."
18) "Generally good concept, unsightly design."
19) "If accurate."
20) "They would be a valuable safety measure if accurate and effective."

Some respondents who indicated they think animal detection systems are not good idea provided reasons in the following categories (some spelling and grammar errors were corrected to enhance readability):

<u>False sense of security/personal responsibility</u>

1) "People may be more cautious in this area as a result of the system but then let up their guard in other areas. They should always drive defensively."
2) "Warning signs are more than adequate. If you rely on detection systems and they fail or animal migration patterns change, the consequences are obvious."
3) "No, they provide a false sense of security. An animal can bound out the forest on to the road too quickly for the detection system to provide any warning."
4) "I don't think people should out drive their headlights and they should be aware of the animals in the specific area in which they are driving."
5) "I feel people will depend on the warnings and be less attentive when driving."
6) "You should always be wary of animals on the road."
7) "Make people reliant on technology and forces them into a false sense of security."

<u>Ineffectiveness/cost</u>

1) "They are not a good idea until they can be proven to be effective."
2) "Way too expensive for a system that doesn't work."
3) "Signage is more than sufficient."
4) "Inconsistent, a more permanent system would ultimately be more productive. i.e.- special crossings in frequently used animal routes."
5) "Because animals are present throughout the state and wander at will, crossing whenever they want to."
6) "Waste of money, if gas was cheaper like 1.50 / gallon then yes."

<u>Aesthetic concerns</u>

1) "Just too much (signs, wires too much)."

Combination of reasons

1) "I think they are ugly and an eyesore in an otherwise beautiful stretch of highway. I also think it makes people dependent on them, and they will rely on the system rather than their eyes and judgment."
2) "Roads should be traveled at their own risk, it is not the tax payer's job to alert unfocused drivers."
3) "They are a waste of taxpayer's monies. The driver of the vehicle should assume responsibility for his driving actions without the help of the government or some environmentalist society. The less government intervention in our daily lives the better off we are."
4) "If you drive in the park where you know there are going to be animals you should slow down and expect to see animals on or near the road and not have to look at ugly poles and sensors along the road that don't work most of the time anyway."
5) "Develops false dependency and intrusive visually."

Some respondents who indicated they did not know if animal detection systems are a good idea provided the following comments:

1) "Unfamiliar with how it works and/or its effectiveness."
2) "Animals can cross the road anywhere."
3) "Yes but people don't understand the signal."

19. Animal detection systems are designed to warn you when animals are on or near the roadway. For you to be confident in such a system, what percentage of large animals (deer and larger) that approach the road do you think should be detected by an animal detection system?

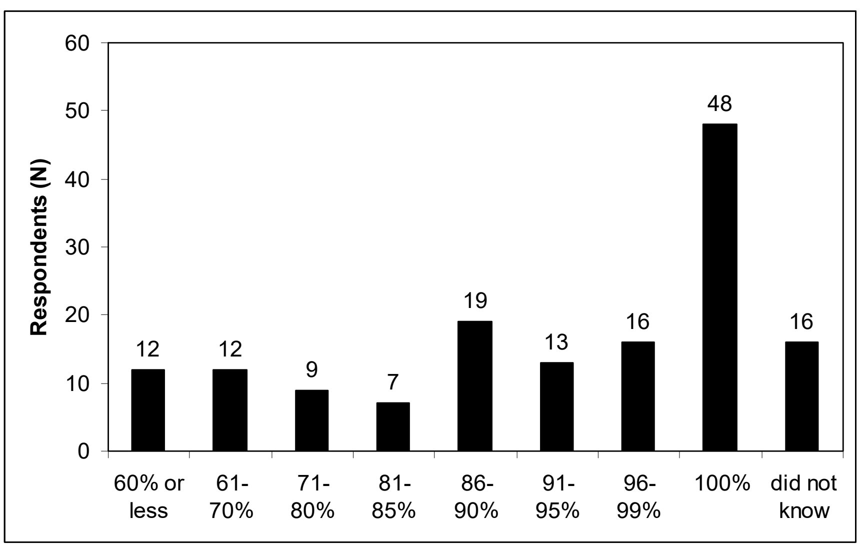

Figure D.22: Percentage of large animals (deer and larger) that should be detected when they approach the road (N=152)

20. Certain weather conditions, low flying birds, falling leaves or high vegetation can result in a "detection" and the activation of the warning signs. What percentage of the total number of detections would you allow to be "false" (that is, the warning lights are on, but there is not really a large animal present)?

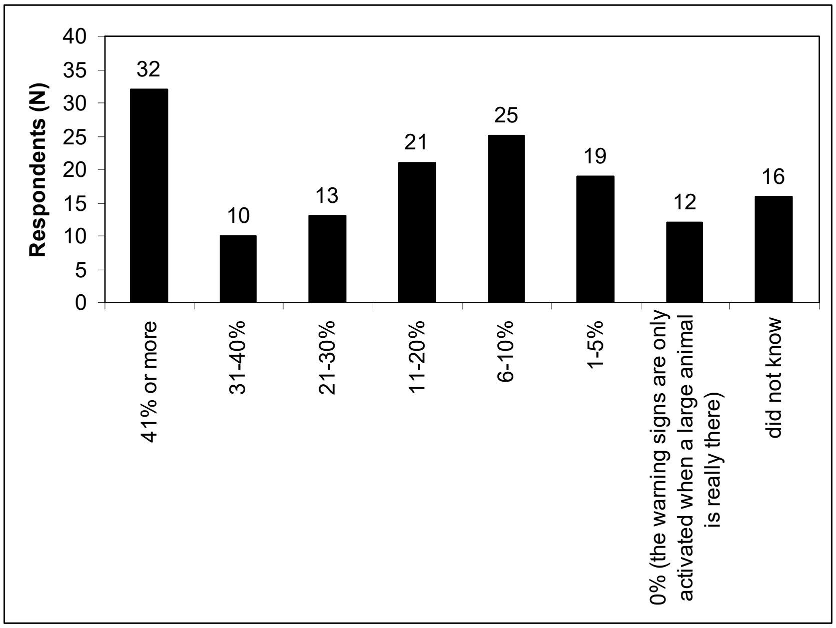

Figure D.23: Percentage of the total number of detections that the respondents would allow to be "false" (N=148)

21. What percentage reduction in collisions with large wildlife (deer and larger) would you want to see or expect to see as a result of the presence of an animal detection system?

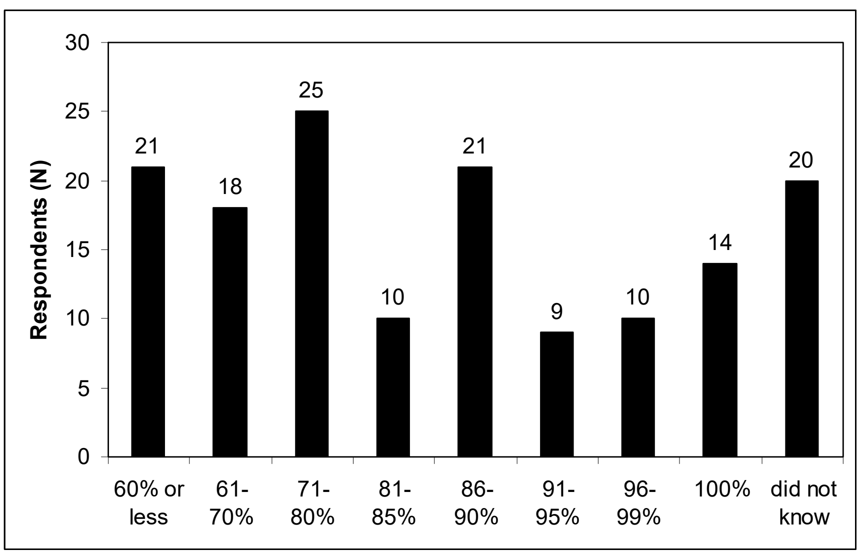

Figure D.24: Percentage reduction in collisions with large wildlife species that the respondents would like to see as a result of the presence of an animal detection system (N=148)

22. Animal detection systems cost money, but they can also save money through preventing collisions. In your opinion, what should be the balance between the cost and benefits of animal detection systems?

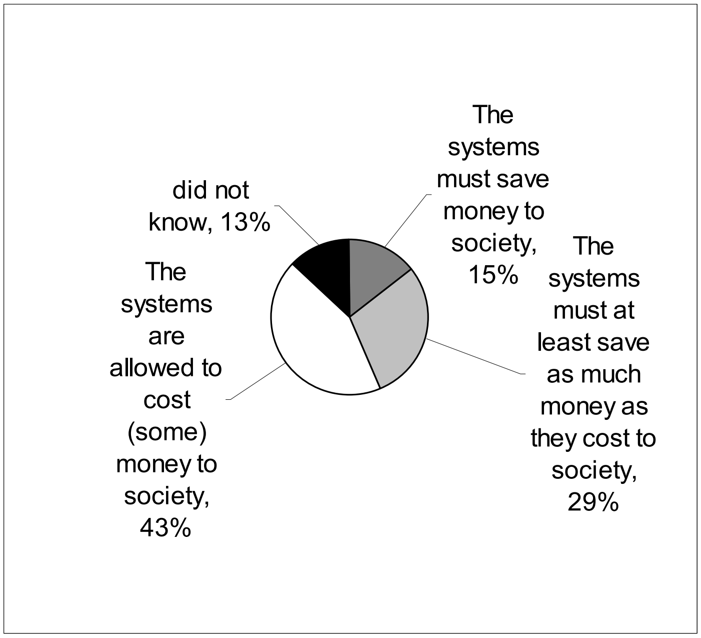

Figure D.25: Balance between the costs and benefits of animal detection systems (N=149)

23. Please rank the importance of potential improvements of animal detection systems. Use a five-point scale where 1 means it is not important and 5 means that it is very important. (Circle one number per question).

a. Reliable systems

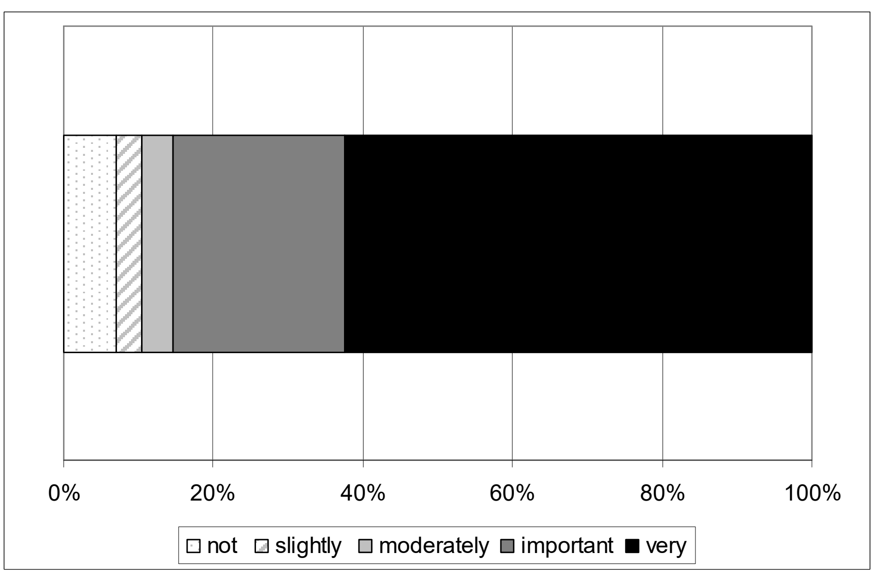

Figure D.26: Importance of potential improvements in system reliability (N=144)

b. Clear, easy to understand warning signals

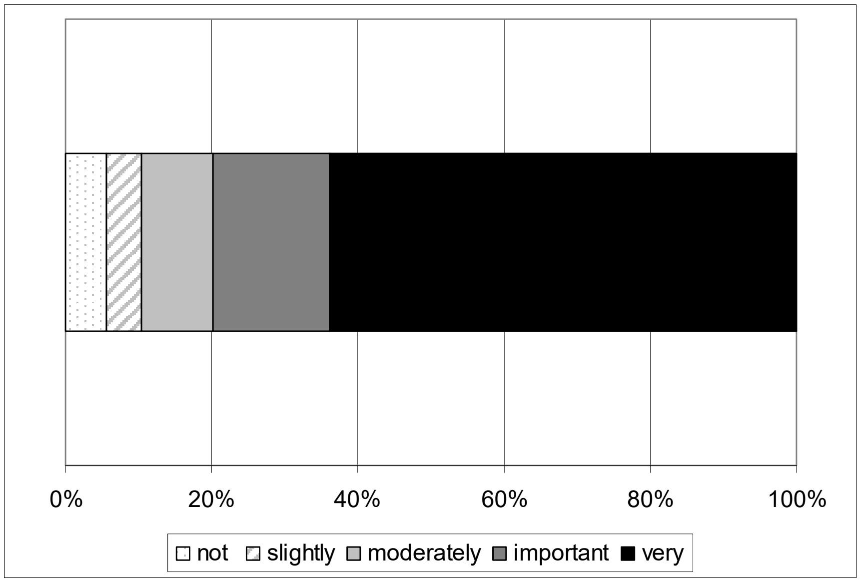

Figure D.27: Importance of clear and easy to understand warning signs (N=144)

c. Small, unobtrusive systems

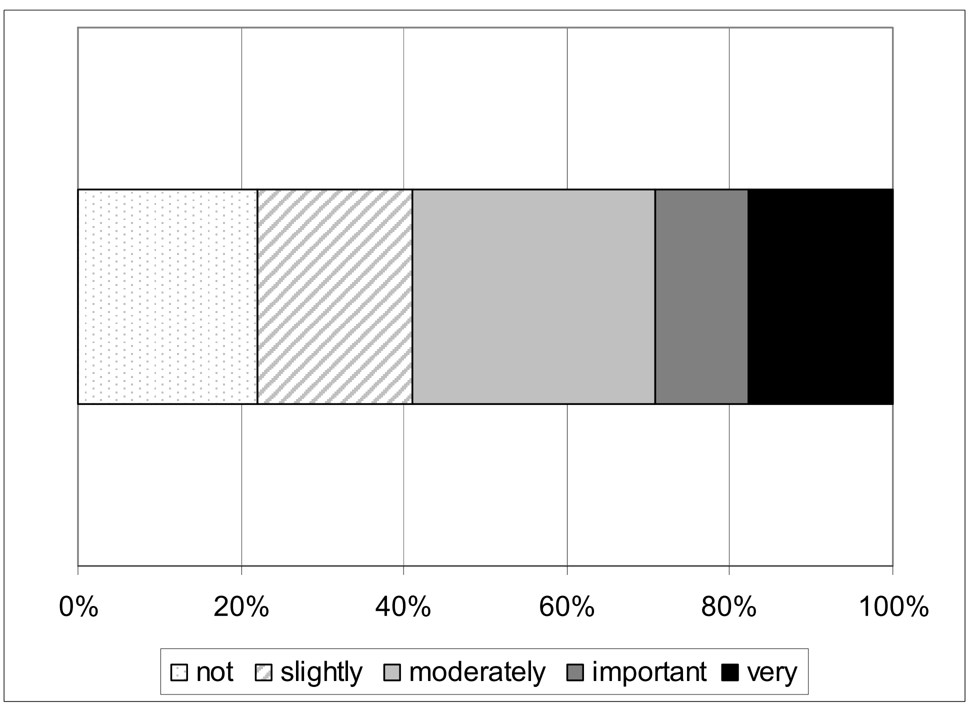

Figure D.28: Importance of small and unobtrusive systems (N=141)

d. Inexpensive systems

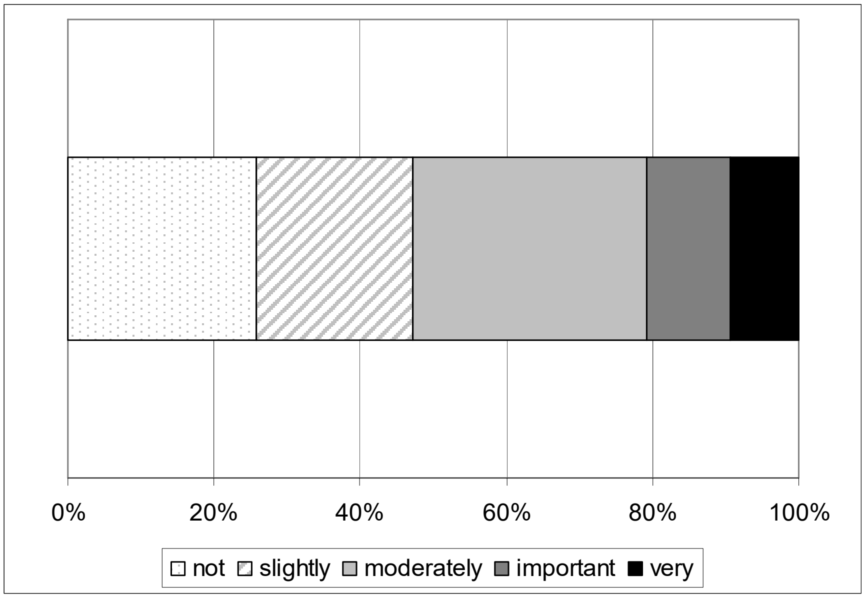

Figure D.29: Importance of inexpensive systems (N=140)

Seven respondents offered the following comments on other potential improvements.

Education
1) "Education so people know what flashing means."
2) "It's more important to teach the driver to pay attention to their driving and quit expecting someone else to make their trip safer."

Unintended accidents
1) "The system shouldn't create more accidents than it prevents."

Appropriate location
1) "Systems installed in the areas most heavily used by wildlife."

Cost
1) "Not worth the cost."
2) "All detection systems are a waste of the tax payers' monies."
3) "Can cost some money to society in the beginning, but should save as much money as it costs in the long run."
4) "Insurance companies should help fund these systems rather than payout to customers and collision repair centers!"

24. If you have any comments or thoughts related to the animal detection system along Hwy 191 or animal detection systems in general, please use the space below (typos were corrected to enhance readability):

For

1) “Please continue to work to design any system improvements that help this system to be more successful. It is NOT a waste of time or money!”
2) “If they help and I assume they do, I would like to see more of them.”
3) “Any system to avoid hitting animals is necessary.”
4) “I hope that it becomes more effective, I was under the impression that it isn't or wasn't fully functioning. I do appreciate the idea behind the system.”
5) “Continue to use them and install more!”
6) “The costs of the systems should be of little importance. When our government spends billions of our tax dollars starting wars under false pretenses, the least they could do is fund projects at home that actually make a difference in the lives of people, not to mention animals. I feel these systems are not luxuries but necessities that ensure safety for all us critters.”
7) “They are a good idea! They can help prevent needless animal deaths and injuries, and also human deaths, injuries, and vehicle damage.”

Neutral

1) “In the past dozen or so times that I've driven through there, I've only seen the lights flash once... but no animals were around.”
2) “Thanks for letting the public take this survey.”
3) “My job takes me up and down 191 very often. I don't see many large animals in that area at all. Maybe they only come out at night when I for the most part don't travel on that road. I do find myself on that road after dark.”
4) “I am not sure the actual detection is as important as anything that really alerts drivers to the high possibility of large animals.”

Against

1) “I wish you good luck with your study even though I think it is mostly a waste.”
2) “Take it down!!!”
3) “Remove the system from 191. I don't believe that this system, nor any other system, is 100% reliable. These systems just give the driver a false sense of protection.”
4) “Scrap it.”
5) “Take the system down, the elk are further up the road typically near Daley Creek or back at Specimen Creek, not where the sensors are currently and they are a huge eye sore to Yellowstone National Park.”
6) “The system doesn't belong in a beautiful National Park and is way too expensive of a system that doesn't work and hasn't worked since it was installed.”

Suggestions/questions

1) “The road through Sequim, Washington would be a good test area for one type of system, avoiding elk collisions.”
2) “Yes, get the trucks off 191 and you will not lose as many animals. Do you think 18 wheel truckers care about an animal detection system?”
3) “I wonder how many people seeing the flashing lights cause a hazard because they stop or slow down to LOOK for the reason the light is flashing. If there is an accident somewhere else where the detection system is NOT will they try to sue because the detection device wasn't in the 'right' place?”
4) “If and/or when this system can be proven to work, wonderful, until then, take it down and do further study.”

5) “Again, this system was installed in an area that, from my experience in 25 years of driving this road, does not see much wildlife traffic. Were these systems installed elsewhere they need to be in places where wildlife are known to cross frequently.”
6) “I have driven by the system 2 times (round trips) in the past 2 weeks and it was activated 2 of the 4 times. There were no animals or tracks or any animal sign present. I have driven that section of the road hundreds of times since the system was installed, and I have never seen any animals on the road where the system is. It needs to be moved to an area where there are more animals. A good spot would be from the Fan Creek parking lot, north to where the Gallatin River Passes under Hwy 191. The system needs to be more reliable, especially in the winter when there are many more elk near the road.”
7) “Maybe a permanent flashing light above a sign would be a more cost effective way of warning drivers.”
8) “As stated before, a detection would better serve the travelers on US 89 in the Tom Miner area north of Yankee Jim Canyon. Thanks.”

Request results

“I'd like to see results of a study of whether these have saved animals' lives; without having this makes it difficult to know if it is worth it or not. Perhaps the study is out there and I just haven't seen it.”

APPENDIX E: SELECTED MEDIA COVERAGE OF THE PROJECT

Selected Media Coverage of the Project

Date	Newspaper or Magazine	Title
12 Sep ‘06	Tech News daily	Wildlife-Vehicle Collisions and High-tech Equipment
12 Sep ‘06	Newswise	High-Tech Equipment May Help Reduce Wildlife-Vehicle Collisions
12 Sep ‘06	Helena Independent Record	Invention may reduce wildlife-car collisions
12 Sep ‘06	India Gazette, India	Roadway animal detection system developed
12 Sep ‘06	Testand Measurement.org	High-Tech Equipment May Help Reduce Wildlife-Vehicle Collisions
12 Sep ‘06	UPI.com United Press International	Roadway animal detection system developed
12 Sep ‘06	EurekAlert	High-tech equipment may help reduce wildlife-vehicle collisions
13 Sep ‘06	The Engineer & The Engineer Online, United Kingdom	Putting an end to roadkill
13 Sep ‘06	WebIndia123.com, India	Roadway animal detection system developed
13 Sep ‘06	NewsGuide.us	High-tech equipment may help reduce wildlife-vehicle collisions
13 Sep ‘06	California Science and Technology News	High-Tech Equipment May Help Reduce Wildlife-Vehicle Collisions
14 Sep ‘06	Innovations report, Germany	High-tech equipment may help reduce wildlife-vehicle collisions
20 Sep ‘06	Billings Gazette	Warning for wildlife system gets going
23 Sep ‘06	Jackson Hole Star Tribune	Researchers fix glitches in wildlife-detection system
23 Sep ‘06	Caspar Star Tribune	Researchers fix glitches in wildlife-detection system
5 Oct ‘06	USA Today	Systems warn drivers of deer in headlights
5 Oct ‘06	Technology Review	Reducing Roadkill. Researchers in Montana have developed a radio sensor system to combat highway accidents involving wildlife.
Nov ‘06	Better Roads Magazine	Critter Crossings and Sensors Keep Wildlife, Motorists Apart. Road Science.
Jan ‘07	Biophotonics	Detection systems reduce collisions with wildlife on rural highways
20 Mar ‘07	Psych Central	High-tech equipment may help reduce wildlife-vehicle collisions
17 Jul ‘07	Forbes.com	States Seek to Curb Deer-Related Crashes

Date	Newspaper or Magazine	Title
27 Jul '07	Bozeman Chronicle	Experts search for ways to curb deer-related traffic accidents
27 Jul '07	The Guardian, United Kingdom	States Seek to Curb Deer-Related Crashes
30 Jul '07	ESPN Outdoors	Experts search for ways to curb deer-related traffic accidents
30 Jul '07	Sioux City Journal	Experts search for ways to curb car-deer crashes
25 Sep '07	Yellowstone Newspaper	Experiences with and opinions on the animal detection system along US HWY 191 in Yellowstone National Park
Oct '07	The Interim, A Monthly Newsletter of the Montana Legislative Branch, Montana Volume XVI, No. 5	Reducing roadkill studies around Montana. Pin down where wildlife cross the road and ways to curb collisions
13 Dec '07	The Big Sky Sun, Bozeman, MT	Explore Yellowstone's Northwest Corner along Highway 191
22 Dec '07	The New York Times	As Cars Hit More Animals on Roads, Toll Rises
22 Dec '07	The Indiana Gazette	Wildlife, vehicle crashes increase nationwide
22 Dec '07	The Gainesville Sun	Cars hit more animals on roads
28 Jan '08	DailyCamera.com, Boulder, CO	Flashing lights may keep elk safe
31 Jan '08	The Denver Post	Study: More cars hitting wildlife on highways in Colorado, nationwide
Mar '08	Safe Passages (American Wildlands)	SURVEY: Experiences with and opinions on the Animal Detection System along U.S. Hwy 191 in Yellowstone National Park
3 Sep '08	Popular Mechanics	Next-gen animal surveillance rig aims to reduce roadkill 2.0
12 Oct '08	LA Times	System acts as wildlife crossing guard. Colorado tries a new way of ensuring safe passage across a notorious highway that bisects an animal migration route
	Wyoming Public Radio	
	WIZ-CBS Radio--Boston	

APPENDIX F: FUTURE ACTIONS FORESEEN BY TAC MEMBERS

Future Actions Foreseen by TAC Members

Pete Hansra, **California** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

Animal-vehicle crashes are a big problem in California. Even after using fences, static signs and reflectors, this remains a major safety issue. We would definitely like to look at advanced technologies to put a dent in the accidents. So this project has been beneficial to us.

- How you plan to use the results of the project within your state.

We have already funded a project to mitigate animal-vehicle crashes using advanced technologies in California and we are going to use lessons learned from the pooled fund project for this project in California..

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

Even though it has not been approved by the final authority, Caltrans is interested in phase III. We looked into taking a lead role but I was informed that we don't have any federal obligation authority left to fit this in. So we won't be in a position to take a lead role.

Samy Noureldin, **Indiana** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

INDOT did not participate financially in Phase II, find no reliable results from it.

- How you plan to use the results of the project within your state.

INDOT will continue to pursue means to reduce/eliminate Animal Vehicle Collisions through other technologies that are easier to install, easier to align, practical to maintain, functional and provide effective results.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

INDOT has no plans to participate in Phase III.

Troy Jerman, **Iowa** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

Although our state has not realized any direct benefits from this pooled fund study we do feel that what was done has been important. If the group continues with phase III as proposed there may be products more applicable to our terrain and animal movement.

- How you plan to use the results of the project within your state.

I *don't know that we will use the results from this study but the next phase would be most helpful.*

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

Our state would be interested in participating but not in assuming the role as lead state.

Steven Buckley, **Kansas** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

We've learned it is a developing technology with great potential. However, the cost should limit its use to locations with severe problems where more conventional methods have not proven effective.

- How you plan to use the results of the project within your state?

At present, we do not have a plan to experiment with this device in Kansas. We will, however, make the results of this study available to our traffic engineers and field maintenance engineers for their consideration. Our large game in Kansas is limited to deer. The problem is so wide-spread the only solution that would make a difference in our animal-related crash numbers would have to be applied systematically and therefore low-cost. One question we may pursue relative to our Strategic Highway Safety Plan is specific to lane departure crashes: what percentage of our lane departure crashes are the result of the driver swerving to avoid an animal in the roadway, missing, and running off the road? This crash type would not be coded as "animal" in our database—it is only sometimes coded with "animal" as a contributing circumstance. In other words, do animal-related crashes contribute to fatal and serious injury crashes to a degree greater than the data shows? If this proves the case, we may have an interest in applying more high-cost solutions, such as detection systems and fencing.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

Our emphasis is on reducing fatal and serious injury crashes on all public roads in Kansas. A very small percentage of fatal crashes involve deer or other animals. We will wait to hear from our traffic engineers or field maintenance engineers. If they want to experiment with the device somewhere KDOT may participate in a new pooled fund project. If there is no interest, we probably will not participate.

William Branch, **Maryland** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

This research project has shown that there are advanced technologies which can be successfully developed that will add to the toolbox of workable solutions needed to reduce animal vehicle collisions.

- How you plan to use the results of the project within your state?

Maryland plans to remain involved in the evolution of this technology toward the goals of greater system efficiencies, reduction of the aesthetic footprint along highway rights of way, and determination of system effectiveness.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

Maryland is interested in participating in phase III.

Deb Wambach, **Montana** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

The benefits of this project to MDT have been 1) increased exposure to a relatively new technology available for animal-vehicle collision mitigation; 2) increased awareness of the technology limitations, trouble-areas or short-comings, reliability, advancements and advantages; 3) better understanding of appropriate applications, site conditions, cost and level of effort required for deployment and maintenance; 4) consideration regarding the potential applications for such technology in MT as one tool, with the potential for positive cost-benefit ratios, to address the safety of our travelers and reduce wildlife mortality on our highways.

- How you plan to use the results of the project within your state?

MDT staff has recently made recommendations regarding the consideration of animal-detection system technologies on a few proposed projects in areas with elevated road kill and animal-vehicle collisions. The results from this study, as well as the Lewistown study, will help guide those considerations with regard to the type of system and vendor, the cost-benefit analysis, expected reliability and effectiveness, and system deployment and maintenance requirements. As these recommendations are accepted, MDT will continue to experiment with various animal-detection system technologies, using the results of this project and the Lewistown project as guidelines and state-of-the-knowledge to date.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

Our state is very interested in continuing our participation into Phase III of the Animal Detection System TAC, or a related project. However, as with many, if not all, of the participants, our budget is very tight right now as well. We would have to bring this research effort forward to the Research Review Committee (RRC) to compete with all the other research proposals. The RRC will deem whether the proposal is a high priority for research funding at this time. Some advantages for this effort are 1) Our previous and long-term involvement in the effort to date, 2) not *having to specifically maintain/trouble-shoot an experimental site here in MT for the purposes of data collection, and 3) the pooled fund nature of the project, sharing the costs and the results with a nationwide team of DOT's. Of course, there are no guarantees. The RRC will meet in late October (too soon to Champion this project) and possibly again in early December. The RRC will meet in 2009 as well, and this project can be championed at any of these meetings, depending on the timing of the group's momentum and decisions for the pursuit of Phase III or a related project.*

Greg Placy, **New Hampshire** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

We have been made much more aware of technology that exists to help with the reduction of Animal/Vehicle Crashes. The result of awareness has been to take a better look at projects to determine if there is something that can be done to help reduce crashes.

- How you plan to use the results of the project within your state?

This information will be used to show that the technology does work. If the cost becomes more affordable and the reliability is improved sites may be considered for installation.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

New Hampshire is interested in reducing animal-vehicle collisions. If the project is to monitor installations and promote consistent research to determine effectiveness and reliability we would probably participate if funding is available.

Shawn Kuntz, **North Dakota** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

North Dakota definitely has a problem with large animal crashes, mainly deer. It is good to know that there are some countermeasures and technology available that may assist North Dakota with animal crashes. I believe there may be limited areas in the state that potentially may benefit with this type of technology. One major benefit is that North Dakota now has access to research data that would not have been financially feasible to acquire on its own.

- How you plan to use the results of the project within your state?

Mainly as reference information. I am not aware of any push to implement this type of system in the near future. As other states such as Montana and California implement similar systems then more information will be available. If these other states have a good success rate then it may be possible that North Dakota may follow with a similar program.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

North Dakota may be interested in participating with a new pooled funds project. The bottom line is money. How much would North Dakota be asked for? I think North Dakota may be interested in a pooled funds database that would pool all the information available from the other states with animal detection systems in operation. I cannot say that North Dakota would be interested in another similar project as the West Yellowstone study. That is not for me to decide.

June Ross, **Oregon** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

The project provided a necessary opportunity to test a new technology for animal detection that has since been developed as a marketable, cost-effect system for reducing animal-vehicle collisions.

- How you plan to use the results of the project within your state.

Oregon Department of Transportation Geo-Environmental Section has been cooperating with the Oregon Department of Fish and Wildlife (ODFW) on a mapping project to identify locations where there are frequent animal-vehicle collisions. They are using this information to focus on the areas of greatest concern. In a 150 mile section, during a two-and-a-half -year period, there were records that 1500 animals were killed. ODFW estimates that anywhere from 2-8 times the number of kills wander off highway. At this point, ODOT is looking at various under-crossing and fencing options. The results of the pooled fund study will be shared and the installation of an animal detection system encouraged.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

Oregon may participate in a new pooled fund study. Our participation will depend partly on the interest of those involved in current animal-vehicle collision countermeasure efforts to implement a system such as was studied in this project.

Jon Fleming, **Pennsylvania** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

Unfortunately the issues surrounding the Pennsylvania site have had a negative impact on the perception of animal detection systems for PennDOT. I believe the benefit of the study is greater research in the operation and reliability of detection systems is necessary before further research dollars are spent investigating the impact of the system on the motoring public.

- How you plan to use the results of the project within your state?

As a reference for any future studies or public inquires.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

As with the Phase 3 study, PennDOT has elected to expand research funds in other areas.

James Merriman, **Wisconsin** Department of Transportation

- o What you think the benefits of the project have been (to your state and overall)?

WisDOT benefits directly as it provides:

- *Efficiency and consistency of pooled fund research distributed among participating states and applied to a common safety concern*
- *Uniform testing protocol and data collection methodology for animal vehicle collision warning systems among concern states*
- *Encourages development of new technologies and standards for equipment, field testing, and data collection for future consideration*
- *Provides a field location for testing current and future technologies*
- *Provides an assessment of maintenance operations and costs associated with animal vehicle warning systems tested*
- *Data generated from the field provides greater confidence in the capabilities and liabilities inherent with each system tested*
- *The project provides necessary information needed to assess alternative tools available to minimize and mitigate animal/vehicle collisions.*
- *information gathered and included in a published report provides documentation needed to prepare reasonable and informed responses to public inquiry*
- *researching and investigating reliable, cost effective systems that may protect the public from animal vehicle collisions demonstrates commitment to overall safety of Wisconsin's roads*

- o How you plan to use the results of the project within your state?

The results of this project provided WisDOT with:

- *A same common basis for public response*
- *Information valuable for the development of preventative measure alternatives analysis and discussion when implementing public policy and procedures*
- *Discussing costs per mile for installation and necessary maintenance operations*
- *Detailed assessment of equipment reliability and effectiveness*
- *An evaluation of warning system tools available in the market place that when paired with a "hot spots" analysis and prioritization can be accurately assessed and compared to other alternatives under discussion for selection and implementation at specific locations*
- *A research report decision makers can refer to with documentation for informed and consistent public response.*

Wisconsin is a state with the third highest white tailed populations in the county. Deer vehicle collisions are not rare. Methods to reduce them are a concern and subject of continued public scrutiny.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

  The need for Phase III is to prepare formal reliability and effectiveness standards. Phase III would provide detailed, uniform criteria decision makers could use to compare reliability and effectiveness of animal/vehicle warning technologies. Wisconsin has participated in the project since research began in 1999. Without phase III formalization of standards and data collection protocol for equipment would proceed on a case by case basis by individual states. Expenses to states considering mitigation alternatives would increase geometrically as the number of states pursuing them increases. Continued evaluation of current and new technologies would be jeopardized and the benefits of efficiency, expenditures and consistency of the past pooled fund research would be lost.

  Yes, Wisconsin is interested in participating.

Kevin Powell, **Wyoming** Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

I believe this study was quite beneficial in that it notably advanced the knowledge basis (state of the science) on Advance Technology Animal/Vehicle Crash Mitigation Measures as described in Phase II report.

- How you plan to use the results of the project within your state?

As noted in in the report, system development and deployment was time consuming and numerous technical problems were encountered. This is not un-expected for new technologies undergoing research and development. However Wyoming will likely be cautious about further deployment along our highway right-of-ways of animal detection and warning systems until further developments particularly in the area of increased system reliability with reduced maintenance are achieved. The results of the Animal Detection Systems Test Bed at Lewiston along with Phase III of this study, if it proceeds, could help advance developments and reduce these concerns.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

I can not say for sure if WYDOT would participate in Phase III. The decision to support Phase III would be made by our research advisory committee and it is always difficult to know in advance what a committee decision will be. Due to WYDOT's past notable involvement in this area of study I suspect that Wyoming will have strong interest in a Phase III proposal. However, WYDOT has invested a notable amount of research dollars in to a variety of animal/vehicle crash mitigation strategies but now budgets are becoming more constrained such that it may be difficult to continue to secure support. So honestly the research advisory committee decision to support on *not support Phase III could go either way. I can say for sure that Wyoming would not care to be the lead state.*

Kyle Williams, **New York** State Department of Transportation

- What you think the benefits of the project have been (to your state and overall)?

The benefits for NYSDOT from the advancements realized as a result of this research are important in that there is greater confidence that animal detection systems provide an effective at-grade option for addressing driver safety and highway permeability for large mammals. Specifically, we now have more definitive information regarding system reliability, effectiveness and driver response, comparisons among different types of systems and a firmly established community of practice of practitioners from around the country.

- How you plan to use the results of the project within your state?

The results of this research provide a greater degree of confidence in the effectiveness, at reasonable cost, of at-grade animal detection systems as well as establishing a community of practice on this topic where additional information on systems can be ascertained down the road.

- The current pooled fund project will end. Any additional work will need to be done under a new pooled fund project. Please provide an indication if you think your state will participate.

Funding is tight, but conditionally - Yes.