REPORT NO. CDOH-P&R-R-77-5

HIGHWAY LIGHTING TO PREVENT DEER-AUTO ACCIDENTS

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Final Report
September 1977

Prepared in cooperation with the
U. S. Department of Transportation,
Federal Highway Administration

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-CO-RD-77-5		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
HIGHWAY LIGHTING TO PREVENT DEER-AUTO ACCIDENTS	5. September 1977 6.
7. Author(s) Dale F. Reed, Thomas N. Woodard, Thomas D. I. Beck	8. Performing Organization Report No. CDOH-P&R-R-77-5
9. Performing Organization Name and Address Colorado Division of Wildlife 6060 Broadway Denver, Colorado 80216	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 1478
12. Sponsoring Agency Name and Address Colorado Division of Highways 4201 East Arkansas Avenue Denver, Colorado 80222	13. Type of Report and Period Covered Final Report September 19, 1969 to September 30, 1977 14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U. S. Department of Transportation, Federal Highway Administration

16. Abstract

Deer vehicle accidents have been the cause of considerable property damage and the loss of biotic resources. This is especially the case in rural areas in mountainous terrain where nighttime driver visibility is poor. The purpose of this research was to determine if deer-vehicle accidents were affected by fixed highway illumination. This was done by comparing responses of motorists to deer on the highway and deer responses to the motorists, with and without fixed illumination.

Estimated deer crossings per kill was 9.7 percent higher with the lights on compared to lights off. When a deer simulation was present under lighted conditions mean vehicle speeds decreased by 13.9 km (8.6 miles) per hour with brake lights observed on 50.6 percent of the approaching vehicles.

The Roadway Lighting Committee (1972) recommends lighting standards based on mean horizontal illumination and illumination uniformity ratios for different roadway and area classifications.

17. Key Words	18. Distribution Statement
Deer-Vehicle Accidents, Highway Lighting, Luminance, Visibility Index	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	26	

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IMPLEMENTATION

Following publication of this Final Report it will be submitted to the Colorado Department of Highways Implementation Committee. At that time the two phases of the study will be discussed - The Effectiveness of a Lighted, Animated Deer Crossing Sign and the Effectiveness of Highway Lighting.

The results presented in this report indicate that the Sign should not be recommended for implementation on Colorado's highways. In regard to Highway Lighting: the report indicates that insufficient data is available at this time and the Pooled Fund Study HPR-3(3) currently underway by the authors should provide the data required. A decision as to implementation of that feature will be made following the HPR-3(3) project.

FINAL REPORT
HIGHWAY LIGHTING TO PREVENT
DEER-AUTO ACCIDENTS [a]

Dale F. Reed, Thomas N. Woodard, and Thomas D. I. Beck [b]

INTRODUCTION

The seriousness of the problem of deer (Odocoileus spp.)-vehicle accidents has been documented (Thompson 1967, Puglisi et al. 1974). Besides the loss of the biotic resource, considerable personal property damage is incurred (Woodard and Reed 1974). The problem arises when highways are constructed through habitats occupied by resident, wintering, or spring concentrations of deer or when highways bisect deer migration routes.

Meaningful attempts to mitigate this problem were not initiated until the 1960's (Pojar et al. 1972). Techniques used in Colorado have included the installation of 2.44-m (8-ft) fencing installed adjacent and parallel to highways. A continuing study indicates this fencing may reduce the incidence of deer-vehicle accidents (Reed 1975). A 3.05- X 3.05- X 30.48-m (10- X 10- X 100-ft) concrete box underpass was constructed under Interstate 70 near Vail, Colorado, and with associated 2.44-m fencing was effective in allowing deer to

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[a]Covers a period from September 19, 1969 to September 30, 1977. The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration

[b]All are wildlife researchers with the Colorado Division of Wildlife.

continue historic migration movements (Reed et al. 1975).

The installation of 2.44-m fencing and underpasses usually must be included in original highway construction because funds for later installation could only be derived from highway maintenance budgets (Pojar et al. 1972). Also, construction of underpasses would result in disruption of the roadbed. There are important deer-vehicle accident areas on existing highways so the need exists for other effective and possibly less expensive techniques or structures to reduce deer-vehicle accidents.

Evaluation of the effectiveness of wildlife warning reflectors or "deer mirrors" have produced dissimilar results, probably because of poor study design which does not preclude biases from seasonal variation. Gordon (1967), after reviewing results from other studies, concluded that warning reflectors were not effective in reducing deer-vehicle accidents.

Evaluation of signs warning drivers of deer crossing areas has also produced dissimilar results. Mansfield and Miller (1975) concluded that 30- by 30-inch symbol-type warning signs reduced deer-vehicle accidents in 11 of 19 study areas in California. Pojar et al. (1975) found that lighted, animated deer crossing signs did not significantly reduce deer-vehicle accidents in Colorado. This study utilized an evaluation technique which eliminated biases due to annual variations and therefore arrived at more valid conclusions. A reprint of the above mentioned publication is included as an Appendix to this report.

Other methodologies that may reduce deer-vehicle accidents include highway lighting. Müller (1967) found that 80 percent of all accidents caused by game in Switzerland occurred from sunset to sunrise. Likewise, more than 92 percent of a sample of 1,441 deer killed on Colorado highways were killed from 1700 to 0900 MST (Myers 1970).

Helms (1969) discussed the factors which affect visual acuity. Brightness is equated with light reflecting from the object. Excessive brightness is detrimental to visual acuity. Contrasts in seeing surface detail and in outline delineation are important. Glare must also be considered when highway lighting is installed. Farber et al. (1971) further discussed the complexity of visibility on illuminated highways. Factors which interact to affect visibility, the contrast of a target object with its surround, include the amount and uniformity of fixed illumination, the amount of vehicle lighting, the target object's location in relation to the fixed illumination sources and the vehicle, the pavement and object reflectance properties, and the level of disability glare.

Gallagher et al. (1972), after a review of pertinent literature, concluded that urban roadway lighting reduced the occurrence of more serious accidents, especially those involving pedestrians. Reductions from 30 to 80 percent were found. Likewise, in a paper from Sweden, Rumar (1975) indicated that many investigations demonstrated roughly 30 to 65 percent accident reduction under road lighting conditions. There has been no research to determine the effect of highway illumination on the occurrence of deer-vehicle accidents, but the factors involved in pedestrian-vehicle accidents are similar. Installation of fixed illumination would increase the night visibility of the motorist and possibly reduce the occurrence of deer-vehicle accidents.

The purpose of this study was to determine if deer-vehicle accidents were affected by the fixed highway illumination on a 1.1-km (0.7 mile) segment of Colorado Highway 82 by comparing responses of motorists to deer on the highway and deer responses to the motorists, with and without fixed illumination. The Division of Highways through its Planning and Research Branch, and in cooperation with the Federal Highway Administration established a research project in which it was considered to be in the public interest to work with the staff of the Division of Wildlife. The research proposed was a study of the effect of lighting a one-quarter mile section of highway for the purpose of: a) Determining the effect of highway lighting on the number and type of deer-auto accidents.
b) Determining whether or not highway lighting affects the location of a deer crossing; that is, will deer continue to cross at their natural location or will they find a new crossing when their natural crossing is illuminated at night. c) Determining the effect of a lighted deer crossing area on the speed and behavior of motorists.

STUDY AREA

The study area is located 4.8 km (3 miles) south of Glenwood Springs, Colorado, on State Highway 82. This 1.1 km (0.7-mile) segment of highway has 4 lanes and a posted speed limit of 88.5 km (55 miles) per hour. The average daily traffic volume within 4.0 km (2.5 miles) of the study area wah 5,706 and 5,111 during the 1974 and 1975 January-March periods, respectively. Adjacent deer winter range is pinyon-juniper (*Pinus* spp.-*Juniperus* spp.) covered slopes and sagebrush (*Artemisia tridentata*) flats to the east and farmland and sagebrush flats to the west. Thirteen 37,000 lumen, 700 watt, clear mercury vapor lamps mounted on 3.05-m (10-ft) arms at the top of 12.2-m (40-ft) metal poles were used to light the highway, spaced at approximately equal intervals, illuminate a 0.40-km (0.25-mile) section of highway. Two lamps installed at each end and spaced at 12.2-m (40-ft) and 183-m (600-ft) intervals provide transition lighting. The lights were connected so that they could be turned on and off manually.

METHODS

The lights were alternately turned on and off for one week periods during January through March of 1974 and 1975. This routine allowed response to the lighting to be monitered during the same general period, thus eliminating annual or monthly variations. The location of each deer-vehicle accident was documented to the nearest meter or 0.2 km (0.1 mile) from markers established along the highway (Reed 1969).

The number of deer that crossed the highway was estimated by making nightly spotlight counts (Reed 1969) and track counts in the median strip when snow conditions permitted. An electronic deer counter was tested earlier and found to be ineffective for this purpose (Traffic Data Systems, Inc. 1969). One crossing was arbitrarily added for every deer killed on the highway. Clover traps (Clover 1956) were used to capture deer during winter months adjacent to and east of the study area. Numbered neckbands were placed on captured deer in order to improve deer crossing estimates.

Vehicle speeds were recorded between 1900 and 2300 MST during 35 nights with an automatic vehicle speed recorder (Newmeyer Model NH-1). Eighty speeds were randomly selected from each nights sample for tabulations.

A deer simulation (transverse section of full taxidermy mount) was placed in the emergency lane of the lighted portion of the highway with the lights on between 1900 and 2212 DST on March 17, 1975. The simulation was located 24.1 m (79.1 ft) beyond the first and 20.1 m (65.9 ft) before the second of two magnetic loops which activate and deactivate the vehicle speed recorder. Motorists response to the simulation was measured by comparing the vehicle speeds collected March 17, 1975 (simulation present, lights on) to vehicle speeds collected March 3, 1975 (simulation absent, lights on) and by making visual observations. Only speeds recorded from 2018 to 2042 and 2118 to

2149 were utilized in tabulations because of probable bias from motorists interference during the other time periods.

Horizontal illumination levels were measured in footcandles (fc) with a General Electric SL480A light meter. The photo-sensitive cell was placed parallel to the roadway surface on the hood of a vehicle traveling approximately 16 km (10 miles) per hour in the driving and passing lanes and along the shoulder of the highway in both directions. Mean horizontal levels for the 1.1- and 0.4-km segments were calculated by averaging the illumination levels estimated from a continuous trace at each 7.6-m (25-ft) distance. Horizontal uniformity levels for the 1.1- and 0.4-km segments were calculated by establishing ratios between the mean horizontal levels ($\overline{X}$) with the mean minimum illumination levels (min $\overline{X}$) (i.e., $\overline{X}$/min $\overline{X}$).

Luminance measurements were taken at sites where the accidents occurred. Luminance values (foot-lamberts) were recorded with a spotmeter, Spectra Model UBA, and were taken on a target at the kill site and on the background as viewed by an approaching motorist. The target was the full taxidermy mount (deer simulation) of a female mule deer and the actual spotmeter recording area was a 26.0-cm (10.2-in) diameter circle midway between the shoulder and hip. Spotmeter readings were taken from a height of 1.3-m (4.3-ft) and a distance of 15.0 m (49.2 ft). For background luminance readings the spotmeter was placed 60.0 m (196.9 ft) from the kill site, resulting in a target area diameter of 102.0 cm (40.2 in). The taxidermy mount was removed during this background measurement. Measurements were taken between 0400 and 0600 to minimize traffic interference. Background luminance (Lb) and target luminance (Lt) measurements were transformed into a visibility index (VI) by the following equation (Gallagher and Meguire 1974):

$$VI = \frac{C(RCS_{Lb})}{5.74}(DGF)$$

where $C = \frac{Lb-Lt}{Lb}$,

RCS = Relative contrast sensitivity for the recorded background luminance,

and DGF = Disability glare factor = 1.0

RCS values are obtained from standard tables (Gallagher and Meguire 1974). VI values can then be compared to standards established for urban lighting requirements. These values also provide a better description of the visibility of deer in the lighted portion of the study area; which, in light of the poor horizontal uniformity ratio in the lighted section (15.0:1), should allow a more refined analysis of the effectiveness of highway lighting.

DATA ANALYSIS

Estimated deer crossings per kill was 9.7 percent higher with the lights on compared to lights off (Table 1). There was no significant difference in the ratios ($X^2 = 0.73$, $P>0.75$). There were no estimated crossings or kill during the 1976 and 1977 portion of this study. Few deer were observed adjacent the study area (Table 2). The probable reason for the lack of deer in 1976 and 1977 was the mild weather conditions. Although the mean daily temperature (-2.3° C) for 1977 was slightly higher than the previous 3-year mean (-2.7° C), the difference was the lack of snow depth. Snow depth measurements at three sites immediately northeast of the study area averaged 46.4 cm (18.3 in), 27.5 cm (10.8 in), and 8.0 cm (3.1 in) for the January through March periods of 1975, 1976 and 1977, respectively.

The highway lighting did not affect the location of deer crossing in that they continued to cross at their natural location (within the lighted area) and they did not find a new crossing when their natural crossing was illuminated at night. However, there were fewer crossings northwest of the lighted portion of the highway in general during 1974-75, and specifically during lights on (i.e. lower ratios, Table 3). Whether this suggests that deer were attracted to the lighted area is uncertain.

During 1974 and 1975 when the 35 deer-vehicle accidents occurred in the study area, no important or unusual accident types or circumstances were recorded (Table 4). Only on seven nights (four and three with lights off and on, respectively) were there more than one accident per night; thus yielding 1.30 accidents per night when at least one accident occurred.

Mean vehicle speeds per hour with lights on were 79.7 km (49.5 miles) southbound and 79.2 km (49.2 miles) northbound. Mean speeds per hour with lights off were 79.3 km (49.3 miles) southbound and 79.8 km (49.6 miles) northbound. There was no significant difference ($P>0.50$) in southbound mean speeds or in northbound mean speeds ($P>0.40$) with lights on or off.

Mean vehicle speeds decreased by 13.9 km (8.6 miles) per hour when the deer simulation was present. The difference was highly significant ($P<0.001$). Brake lights were observed on 50.6 percent of the vehicles approaching the simulation ($n=85$) from 2118 to 2149 DST. Five to ten percent of the motorists either slowed drastically or showed curious behavior. The evaluation was discontinued because of the apparent risk to the motoring public.

The amount of light available at 12 known kill locations during lights on nights ranged from less than 0.01 to 1.41 fc. Available light at seven of these kill locations was less than 0.01 fc.

The Roadway Lighting Committee (1972) recommends lighting standards based on mean horizontal illumination and illumination uniformity ratios for different roadway and area classifications. Recommendations for the Highway 82 roadway and area classification are 1.0 fc mean horizontal illumination and an illumination uniformity ratio of 3:1. Calculated mean horizontal illumination and illumination uniformity ratios for the 0.4- and 1.1-km segments of Highway 82 lighting were

1.47 fc and 15.47:1 and 1.02 fc and 18.55:1, respectively. These uniformity ratios support visual observations that dark areas were present in the study area during lights on nights.

Since the lighting system was not uniform and because contrast ratios are the most important elements for motorist visibility (Gallagher and Meguire 1974), the spotmeter will be used to make target (deer) and background luminance measurements from which contrast ratio calculations can be made at each kill location. Accordingly, accidents which occur under varying visibilities can be described. This will be accomplished during 1978 and 1979 in another study (FHWA HPR-3[3]). Preliminary luminance measurements (Table 5) have resulted in visibility indices that are lower than minimum levels needed for a roadway with 80.5 km (50 mile) per hour speed limit, although the 2.484 value is approaching the level where 85 percent of the motorists can see a target at satisfactory separation distance (Gallagher and Meguire 1974).

Benefit-cost analysis was applied to three methods of reducing deer-vehicle accidents for comparison purposes. The analysis followed procedures described by Howe (1971). Benefits for which values were available were the potential savings accrued by reductions in deer-vehicle accidents and the consequent vehicle repair cost. Savings by reduction in personal injury and death were omitted because of difficulties in obtaining reliable values. No value was assigned to deer. No monetary values were assigned for aesthetic considerations, either positive or negative. The benefit:cost ratio for highway lighting is 0.29:1. This ratio is only slightly higher than the one for the lighted, animated deer crossing sign and considerably lower than for the average of six 2.44-m (8-ft) fences (Table 6).

CONCLUSIONS AND RECOMMENDATIONS

The highway lighting did not affect the location of deer crossings in that deer continued to cross at their natural location when it was illuminated at night. If any effect was detected, it was that a greater proportion of deer crossed in the highway lighting area after the study was begun and when the lights were on, than before the study was begun and when the lights were off.

No important or unusual accident types or circumstances were associated with the lighting per se, or the 35 deer-vehicle accidents that occurred within the lighted study area. Apparently the speed of motorists was not affected by the lighting. However, when a deer simulation was present, motorists significantly reduced their speed. Motorists' response in the form of increased awareness was not sufficient to significantly affect the deer crossings per accident ratio. The 9.7 percent reduction may be due to chance. Contingencies of the small sample size warrant cautious interpretation of these data.

In addition, there was considerable variation in horizontal illumination levels within the study area during lights on nights. However, target contrast ratios are the most important elements of motorist visibility. Such ratios are expressed in the calculations of visibility indices. Preliminary measurements indicate that some visibility indices in this lighting study are low; hence some sample accidents may have to be excluded, exacerbating the sample size problem.

Because of the need to increase accident sample size (and consequently the confidence of study results) and to complete contrast measurements at accident sites, it is recommended that this study continue during 1978 and 1979 under auspices of the Federal Highway Administration HPR-3(3) pooled fund supported by Idaho, Colorado, Nevada, Oregon, and Wyoming.

ACKNOWLEDGMENTS

Denis E. Donnelly and Rich Griffin of the Colorado Division of Highways measured and analyzed the horizontal illumination levels. Burrell B. Gerhardt, then of the Colorado Division of Highways, provided direction, herewith acknowledged with appreciation.

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TABLES

Table 1. Estimated deer crossings and total accidents in the Highway 82 lighting study area during 1974 and 1975.

	Lights OFF	Lights ON
Estimated deer crossings	1581	1637
Number of accidents	18	17
Crossings/accidents	87.8	96.3

Table 2. Mean deer observations during spotlight counts and total kill in the Highway 82 lighting study area from 1974 to 1977.

Year	Mean count	Total accidents
1974	27.1 (n=71)	13
1975	40.3 (n=98)	22
1976	0.3 (n=65)	0
1977	0 (n=5)	0

Table 3. Estimated number of deer crossings immediately northwest, within, and southeast of the lighted portion of Highway 82 before (1972-73) and during (1974-75) the lighting study and in 1974-75 when the lights were on and off.

Year	Number of crossings			Ratio[1/]
	NW (0.8 km)	Within (1.2 km)	SE (0.8 km)	
1972-73	565	2,006	72	0.32
1974-75	398	3,218	83	0.17
OFF	237	1,581	53	0.18
ON	161	1,637	30	0.12

[1/] Determined by: $\text{Ratio} = \frac{\text{NW} + \text{SE}}{\text{Within}}$.

Table 4. Type of accident and circumstances related to accident frequencies while the lights were on and off during 1974 and 1975.

Type or circumstance	Number		
	OFF	ON	TOTAL/AVG.
Accidents per night[1/]	0.18	0.17	0.18
Accidents per night when at least one accident occurred	1.29	1.31	1.30
Deer killed per accident	1.00	1.00	1.00
Fixed-object accidents	0	0	0
Motorist fatalities and injuries	0	0	0
Multi-vehicle accidents involving deer	0	0	0
"Ran-off-road" accidents	0	0	0

[1/] During January 2 through March 26, 1974 and January 3 through April 23, 1975 (196 total nights).

Table 5. Visibility index measurements from kill sites, Highway 82 lighting study area.

No.	Background luminance (Lb)	Target luminance (Lt)	Contrast	Relative Contrast Sensitivity (Percent)	Visibility Index
897	0.043	0.0325	0.244	4.1	0.17
899	0.33	0.00325	0.990	14.4	2.484

Table 6. Benefit-cost analysis of 2.44-m (8-ft) fencing, animated deer crossing signs, and highway lighting.

Structure and Hwy Area Covered (km)	(1) Accident Cost - Year ( ) of Construction	(2) Mean Pre-Structure Mortality	(3) Mean Annual Reduction	(4) PVB [1]	(5) Structure Costs	(6) Associated or Operating Costs	(7) Alternate 42"-Fence Costs	(8) PVC [2] Net Cost	(9) B:C
2.44-m Fencing [3] ($\bar{X}$=3.9)	$ 360 (70-74)	282	76.4%	$978,311	$259,773	$21,934	$38,807	$242,900	4.03:1
Lighted, Animated Deer Crossing Sign (1.6)	362 (73)	(21) [4]	0.7%	671	2,433	600	0	3,033	0.22:1
Highway Lighting (1.2)	396 (74)	(18) [4]	9.7%	8,721	20,683	9,860	0	30,543	0.29:1

1/ PVB = Present value of benefits which is determined by: PVB = (1) X (2) X (3) X 20 X 0.63067; where 20 is the expected life in years and 0.63067 is the discount rate factor (derived from 5.5 percent discount rate).

2/ PVC = Present value of costs which is determined by: PVC = (5) + (6) - (7).

3/ Represents six 2.44-m fences adjacent I-70 and Highway 82.

4/ Projected from off periods since no pre-structure mortality is available when "week-off - week-on" technique is used.

APPENDIX

Reprinted from The Journal of Wildlife Management
Vol. 39, No. 1, January 1975
pp. 87–91

EFFECTIVENESS OF A LIGHTED, ANIMATED DEER CROSSING SIGN[1]

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Abstract: Two lighted, animated deer crossing signs were installed adjacent to State Highway 82 south of Glenwood Springs, Colorado, delineating a 1.61 km (1-mile) segment of highway where deer-vehicle accidents frequently occurred. The signs were turned on and off for alternate weekly periods of 1972 and 1973 during the times when most deer-auto accidents were expected to occur. Numbers of deer crossing the highway were estimated and all deer-vehicle accidents were documented. The number of crossings per deer killed on the highway was 56.9:1 and 56.5:1 with the signs on and with the signs off, respectively. There was no difference in the ratios ($P > 0.50$). Mean vehicle speeds were lower ($P < 0.05$) with the signs on but the reduction in speed was less than 4.83 kmph (3.0 mph). When three deer carcasses were placed along the highway with the signs on, the mean vehicular speed dropped 10.09 kmph (6.27 mph). With the signs off the difference was 12.63 kmph (7.85 mph). There was no significant difference in the mean speeds ($P > 0.50$) when dead deer were on the highway whether the signs were on or off. Apparently motorists did see the sign, but their response in the form of speed reduction and/or increased awareness was not sufficient to affect the crossings per kill ratio.

J. WILDL. MANAGE. 39(1):87–91

Conventional "Deer Crossing" signs have been widely used on public highways in an attempt to warn the motoring public and to reduce deer losses; 27 of 50 states surveyed by Thompson (1967, unpublished report, New Mexico Dept. Game and Fish, Santa Fe), used some such warning sign. The effectiveness of signs in reducing deer-vehicle accidents has not been evaluated to our knowledge. Conventional signs probably have limited effect because they are left in place all year, resulting in motorist habituation to them (Williams 1964).

In view of some of the apparent shortcomings of the conventional deer crossing signs, a lighted, animated prototype was designed and built. This paper reports on the effectiveness of that sign in reducing the frequency of deer-vehicle collisions and on the response of motorists to the sign.

This project was a cooperative effort by the Colorado Division of Wildlife, Colorado Division of Highways, and the Federal Highway Administration.

We thank J. Kelley of the Colorado State Patrol, and the patrolmen under his supervision for their cooperation in reporting and locating dead deer in the study area. H. Swope and J. Vaughn edited the manuscript. L. Green assisted on spotlight counts.

STUDY AREA

The study was conducted 4.83 km (3 miles) south of Glenwood Springs, Colorado, on State Highway 82, a four-lane highway with a speed limit of 96.56 kmph (60 mph). During some years this segment of highway has had the highest frequency of deer-vehicle accidents per mile in Colorado (Yeager 1969). Traffic volume was 1.55 million vehicles (daily mean of 4,255) in 1971, and 1.73 million vehicles (daily mean of 4,741) in 1972. Deer generally winter in the vicinity of the study area from early January to early March; maximum numbers are present in February.

[1] A contribution from Colorado Federal Aid Project W-38-R.

The Roaring Fork River is about 0.80 km (0.5 mile) southwest of the highway and is roughly parallel to it. The area between the highway and river is mostly farmland and small areas of big sagebrush (*Artemisia tridentata*) remain where the land is untillable. At least one haystack (alfalfa) was left unfenced and available for deer use. Dense stands of tansy (*Tanacetum vulgare*) occupy the adjoining highway and railroad rights-of-way adjacent to the southwest side of the highway.

The area immediately northeast of the highway is rough, rocky terrain with southwesterly exposure that supports a good stand of big sagebrush with interspersions of pinyon-juniper (*Pinus* spp.-*Juniperus* spp.) vegetation. Deer usually leave this vegetative cover northeast of the highway, cross the highway, and seek forage and water on the southwest side during the night.

METHODS AND MATERIALS

The lighted, animated deer crossing sign has a reflectorized yellow, diamond-shaped background (1.83 × 1.83 m [6 × 6 ft]) with 4 silhouettes of deer made of neon tubing lighted in sequence from right to left across the sign. During the 1972 evaluation period, the words "Deer Xing" were displayed below the lighted deer silhouettes (Pojar et al. 1972). During 1973 the wording was changed to read "Deer Xing Next Mile" in order to better delineate the critical deer crossing area (Fig. 1). The neon silhouettes were protected by a face plate of 0.95 cm clear plastic glass (General Electric Lexan) designed to withstand high energy impact and minimize damage by vandals. The sign was constructed so it could be swung away easily from approaching traffic. It was always turned away from traffic when not lighted, and this is hereinafter referred to as the off position. In the on position, the neon lights were activated and the sign locked into place facing traffic.

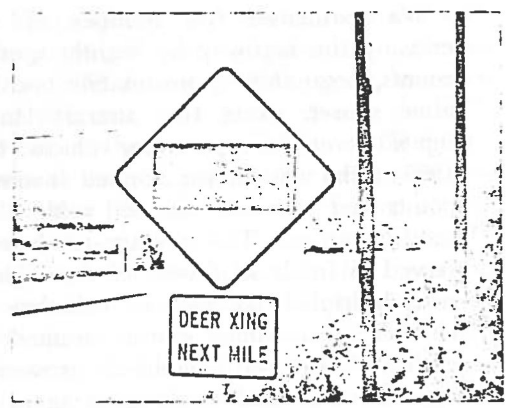

Fig. 1. The lighted, animated deer crossing sign with the modification in the "educational" message. This version of the sign was used during the 1973 evaluation period.

The design of this sign is in keeping with the current trend toward greater use of symbols. Four deer silhouettes incorporated features which provided maximum legibility emphasizing distinctive natural features of the deer silhouette such as the tail and the antlers. Simple construction for minimum maintenance of the electrical equipment was accomplished by using a four-circuit primary flasher and four transformers to control the animation.

Vehicle speed was measured with an automatic vehicle speed recorder (Newmeyer Model NH-1). This instrument records speed and time of day on a paper tape when a vehicle crosses two magnetic loops installed 44.74 m apart. Speed was monitored behind one of the signs at distances of 0.24, 1.05, and 2.41 km (0.15, 0.65, and 1.50 miles). The speeds of nearly all vehicles passing the speed stations between 1800 and 2200 were recorded. Eighty vehicle speeds were randomly selected from this sample for tabulation. Speed data were not collected when the road surface was not dry.

We estimated the number of deer crossing the highway by nightly spotlight counts, beginning approximately one hour after sunset, using two aircraft landing lights operated from a motor vehicle (Reed 1969). The vehicle was stopped at selected points and the area scanned with a 20× spotting scope. The number of deer observed in fields southwest of the highway was multipled by two to calculate the number of crossings; it was assumed that each deer observed had already crossed the highway once and would cross again that same night. For every deer killed on the highway, one crossing arbitrarily was added to the total crossings for that night.

The highway was checked from a vehicle for dead deer during and after each spotlight count and again the next morning. The highway right-of-way was searched in the area of blood smears or skid marks if no deer carcass was found on the highway. The location and time of accident, and the sex and age of the animal killed were recorded.

Deer crossing signs were turned on and off for alternate weekly periods. This routine allowed response to the signs to be monitored during the same general time period, thus eliminating annual or monthly variations. Signs were turned on about one hour before sunset, then shut off between 0800 and 0900 the next morning. Deer killed during daylight hours were not included in the total kill.

Following collection of vehicle speed data in 1973, motorists' response to three deer carcasses placed in the emergency lane was measured. One night each week (Tuesday) carcasses were placed 45.75, 97.60, and 106.75 m behind the sign where they were readily visible to motorists. The carcasses were placed on the highway approximately two hours after sunset and left for two hours, during which time vehicle speeds were recorded at the station 244 m behind the sign. The procedures were repeated on the same night each week.

The effectiveness of the signs was measured in terms of the ratio of estimated deer crossings per one deer killed.

Table 1. Ratios of deer highway crossings per each deer killed with the lighted, animated deer crossing signs off and on, 1972 and 1973.

	1972		1973		Total	
	Off	On	Off	On	Off	On
No. of weeks	2	2	6	5	8	7
Est. crossings	227	163	1,016	975	1,243	1,138
Total kill (deer)	6	3	16	17	22	20
Crossings/kill	37.8	54.3	63.5	57.4	56.5	56.9

RESULTS

Deer occupied the study area in 1972 for only four weeks, resulting in a small sample. The winter of 1973 was relatively severe, which resulted in more deer present in the study area for a longer period (11 weeks). Signs were evaluated for 15 weeks during the 2 years, 8 weeks with the signs off and 7 weeks with the signs on. The deer crossing to deer kill ratio with signs off was nearly identical to the ratio with the signs on, 56.5:1 and 56.9:1, respectively (Table 1). By chi-square analysis, there was no significant difference ($P > 0.50$) between the crossings per kill ratios during 1972 and 1973, or for the composite of the two years.

During 1972 mean vehicular speeds were significantly ($P < 0.05$) lower at all three speed stations with the signs on. These differences were 4.63, 2.28, and 1.87 kmph (2.88, 1.42, and 1.16 mph) at 0.24, 1.05, and 2.41 km (0.15, 0.65, and 1.50 miles) behind the sign, respectively. During 1973 the mean vehicular speeds were again lower at all three speed stations with the signs on (Fig. 2). The differences in mean vehicular speed of 2.41 and 2.57 kmph (1.50

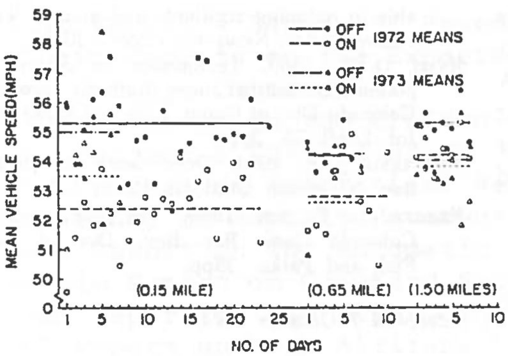

Fig. 2. Vehicular speed at three distances behind the lighted, animated deer crossing sign during the 1972 and 1973 evaluation periods. Each marked point on the graph represents the mean of 80 randomly selected speeds.

and 1.60 mph) at stations 0.24 and 1.05 km (0.15 and 0.65 mile) behind the sign were significant ($P < 0.05$), but the difference of 0.32 kmph (0.20 mph) at the station 2.41 km (1.50 miles) behind the sign was not significant ($P > 0.50$).

The presence of the three deer carcasses lowered mean vehicular speeds 12.63 kmph (7.85 mph) when the sign was turned off. With the sign lighted and carcasses present the mean speed was decreased 10.04 kmph (6.24 mph). The difference in both cases was highly significant ($P < 0.001$). There was no significant difference ($P > 0.50$) in mean vehicular speed with deer carcasses on the highway as the result of the sign being on or off.

DISCUSSION AND CONCLUSIONS

Lighted, animated deer crossing signs were not effective in reducing the number of deer killed while attempting to cross the highway. Crossings per kill ratios were nearly identical with the signs off (56.5:1) and with the signs on (56.9:1). On the average, motorists responded to the signs by reducing vehicle speeds, but the reduction in speed was apparently too small to be of practical importance.

Mean speeds, with the signs on and with the signs off, were significantly different ($P < 0.05$) during the 1972 season, but were not different ($P > 0.50$) during the 1973 season at the station 2.41 km (1.50 miles) behind the sign. It does not seem reasonable that the change in wording of the education sign from "Deer Xing" in 1972 to "Deer Xing Next Mile" in 1973 was the cause of this difference. Mean speed with the signs off was significantly ($P < 0.05$) lower in 1973 compared to 1972, but there was no difference ($P > 0.50$) between years in mean speeds with the signs on. If the motorist was responding to the wording on the sign, he would have increased his speed one mile past the sign. The lower mean speed with the signs off was probably the result of more deer occupying the area during the 1973 season. With more deer in the area, the probability of a motorist observing either live deer or dead deer on or near the roadway was much greater than in 1972.

When the motorist was presented with evidence that a danger existed (i.e., deer carcasses in emergency lane), the response was much greater than when they were merely warned (via the deer crossing sign) of a potential danger. With evidence of danger, the response was the same regardless of whether or not the warning signs were on.

Motorists' response in the form of speed reduction and/or increased awareness was not sufficient to affect the crossings per kill ratio. Since these lighted, animated signs were not effective in reducing the number of deer-vehicle accidents, it seems reasonable to assume that conventional deer crossing signs are not effective either. However, in areas where deer-vehicle accidents are especially numerous, warning signs may be useful for public relations and liability reasons. In these areas conventional signs, which cost $94.00 (1973 prices) each for materials, are more practical in terms of cost and maintenance than the animated sign. A prototype of the lighted, animated sign cost $2,000.00 (1971 prices), and line power (110-V) was needed to operate the lighted portion of the sign.

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Accepted 7 October 1974.

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