TECHNICAL ASSISTANCE REPORT

EVALUATION OF DEER WARNING REFLECTORS IN VIRGINIA

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DISCLAIMER

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ABSTRACT

A deer warning reflector consists of a red, double-sided reflector mounted on posts, similar to those used for roadside delineators along roadways. As vehicles approach and move through the road section, it is purported that the reflector reflects the beam from vehicular headlights across the highway in a moving pattern of low-intensity red light beams, which in turn gets deer's attention and deters them from entering the roadway.

The purpose of this study was to evaluate the effectiveness of the deer warning reflector system. The measure of effectiveness was the change in deer-vehicle collisions on highway segments with and without the reflectors. The number of deer carcasses picked up by crews of the Virginia Department of Transportation was the measure used for deer-vehicle collisions. The level of maintenance activity needed to keep the marking system effective was also monitored.

Deer warning reflectors were installed at 10 sites in Virginia. Each reflector site had a control site that was typically adjacent to the reflector site. The sites were monitored for 6 to 28 months. There was no evidence to suggest that the deer warning reflectors were consistently effective across most sites based on trend and statistical analyses. An experimental section with deer warning reflectors on one side of the road yielded results similar to those for the standard arrangement with reflectors on both sides of the road and control sections. In order for the benefits of the reflectors to exceed their installation and maintenance costs, the reflectors would have to prevent at least 1.14 deer-vehicle collisions per mile per year.

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INTRODUCTION

In the 3-year period of 1999-2001, 10 people were killed, more than 1,500 people were injured, and there was an estimated $31.9 million in property damage in reported deer-vehicle accidents, as indicated in Table 1. There were 15,227 reported deer-vehicle collisions during this period for an average of 5,075 per year. In Virginia, law enforcement officers are required to file a written report to the Virginia Department of Motor Vehicles if a motor vehicle accident results in injury, death, or more than $1,000 in property damage. The majority of deer-vehicle collisions, 91 percent, are property damage only. The average estimated cost of the property damage is $2,300 for the 3-year period.

Although data are not available, the literature indicates that only about 20 percent of deer-vehicle collisions are reported to law enforcement authorities. The Virginia Department of Game and Inland Fisheries (VDGIF) provided the following statement in 1999:

> Although reliable data are not available, it is safe to assume that tens of thousands of deer-vehicle collisions take place in the Commonwealth each year. For example, in Pennsylvania where data on deer-vehicle accidents are monitored, deer-vehicle collisions typically exceed 40,000 annually. If one assumes there are 25,000 deer-vehicle collisions in Virginia annually, with a conservative estimate of $1,000 in damages per accident, then resulting property damage would be at least 25 million dollars.[1]

Given the potential for 25,000 deer-vehicle collisions per year, a substantial hazard exists on Virginia highways.

A review of the distribution of reported accidents by system in 2001 revealed that half of deer-vehicle collisions occur on the primary system (Table 2). The secondary system is next, with 29 percent, followed by the local and interstate roads. Consequently, the Virginia

Table 1. Reported Deer-Vehicle Collisions for 1999-2001 in Virginia

All Systems	1999	2000	2001	Total	%
Fatal Crashes	4	2	4	10	0.07
Number Killed	4	2	4	10	
Injury Crashes	412	385	495	1,292	8.48
Number Injured	486	452	573	1,511	
Property Damage Only Crashes	4,050	4,340	5,531	13,921	91.42
Amount of Property Damage	$7,462,969	$10,702,327	$13,768,210	$31,933,506	
Total Crashes	4,470	4,727	6,030	15,227	

Table 2. Reported Deer-Vehicle Collisions by Road System for 2001

Road System	Number	%
Interstate	610	10.1
Primary	3,006	49.9
Secondary	1,722	28.6
Local	692	11.5
Total	**6,030**	

Department of Transportation (VDOT) embarked on a safety initiative to install a device aimed at reducing deer-vehicle collisions. The selected device was the Strieter-Lite Wild Animal Highway Warning Reflector System. Since the most common application is to warn deer, it is also called a deer warning reflector.[2]

The device consists of a red, double-sided reflector mounted on posts similar to those used for roadside delineation along roadways with horizontal curves (see Figure 1). The red reflector is 6.5 in long and 2 in wide. As vehicles approach and move through the road section, it is purported that the Strieter-Lite marker reflects the beam from vehicular headlights across the highway in a moving pattern of low-intensity red light beams, which in turn gets the deer's attention and deters them from entering the roadway. The shaded area across the roadway in Figure 2 denotes the coverage of reflectors facing the road. Although the light beams are not visible to the motorist, deer that see the unnatural and moving light pattern (referred to as a light fence) are expected not to cross the roadway while the light fence is present. To ensure

Figure 1. Standard and Alternating Back-to-Back Reflector Installations

the entire section of roadway identified as deer-accident prone is protected, markers are placed at a predetermined spacing based on the roadway alignment conditions. The reflectors are mounted at a height of 24 to 30 in. When there is a change in elevation that prevents deer on the roadside from seeing the dim light forming a moving pattern across the road, reflectors are placed on the back side of the post facing the roadside. A light pattern is also displayed off the road, as shown in the down slope area of Figure 2.

Strieter-Lite deer warning reflectors are used in several states and 12 Canadian provinces where a high-density population of deer exists and vehicle-deer collisions are documented. The manufacturer and reports from these jurisdictions reflect a positive result in reducing the accident frequency upon installation of this device.[3] The deer warning reflector system has the potential to reduce deer-vehicle collisions substantially. Such reductions will in turn reduce the costs and injuries associated with such collisions. In a number of states, deer-vehicle collisions were reduced 70 to 90 percent.[3] However, a literature review on deer warning reflectors indicated less promising results.[4] Since there is conflicting evidence regarding the performance of the deer warning reflectors, it was decided that a study was needed to examine how they perform on segments of Virginia roads.

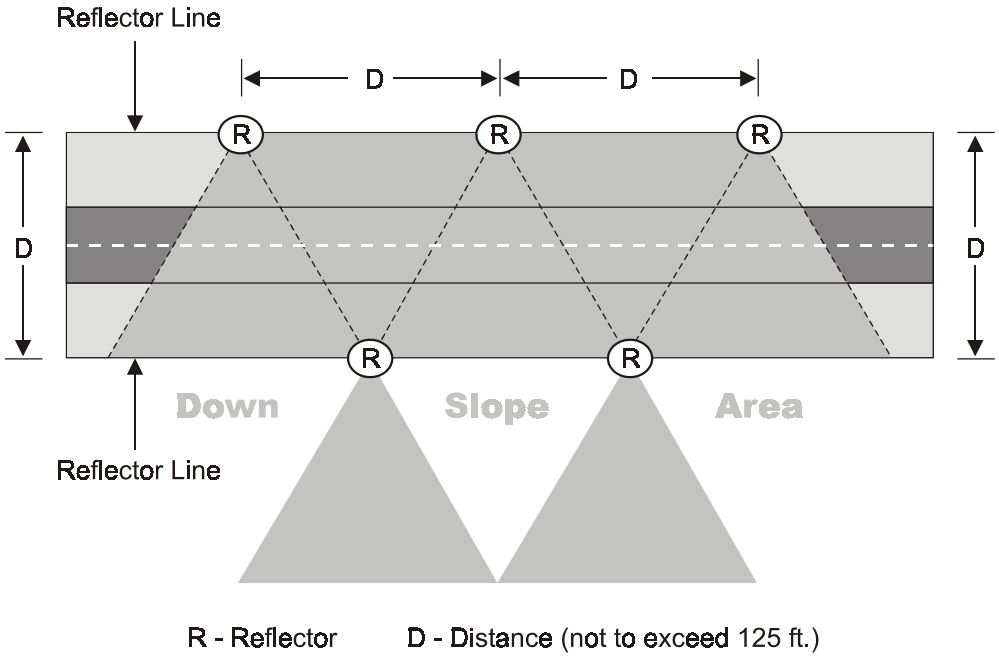

Figure 2. Reflector Coverage On-Road and Roadside with Elevation Changes[2]

PURPOSE AND SCOPE

The purpose of this study was to evaluate the effectiveness of the deer warning reflector system in Virginia. The measure of effectiveness was the change in deer-vehicle collisions on highway segments with and without the reflectors. The number of deer carcasses picked up by

VDOT crews was the measure used for deer-vehicle collisions. The level of maintenance activity needed to keep the marking system effective was also monitored.

METHODS

Five tasks were performed to accomplish the purpose of the study.

1. *Site Selection.* VDGIF staff and VDOT field crews responsible for deer carcass removal were consulted for suggestions for potential study sites and were asked to participate in the study. VDOT and VDGIF staff were asked to review accident data, accompany researchers on site visits, and participate in discussions on deer-vehicle accident issues.

2. *Development of Study Method, Data Collection Plan, and Analysis.* The study method is a comparison of deer-vehicle collisions between the treatment (reflectors installed) sections of roadway and a control section (no reflectors) during the same time period. In most cases, the control section was adjacent to the treatment section. A monthly data collection form, Figure A1 in the Appendix, was developed for use by VDOT field crews who pick up deer carcasses and maintain the reflectors to record pertinent information. The completed forms were submitted monthly, and the researchers used them to develop trend and statistical analyses.

3. *Installation of Deer Warning Reflectors.* The deer warning reflector system was installed at the selected sites. District sign crews installed the reflectors. The president of Strieter-Lite Corporation reviewed each site to verify that the reflectors were installed correctly.

4. *Monitoring of Study Sites.* The study sites were regularly monitored by VDOT area headquarters (AHQ) staff. The primary source of information such as deer carcass pickups and maintenance activity was the monthly forms submitted by VDOT AHQ staff. A survey of this staff was conducted at the end of the monitoring period.

5. *Data Analysis.* The data were analyzed for trends and statistical testing. The Wilcoxon rank sign test was used. This is a nonparametric (distribution free) test of the hypothesis that two distributions are equal against the alternative that the medians are different.[5,6] Two tests were conducted: one at all sites (10 sites) and one at sites with 21 or more months of data (6 sites). The hypothesis to be tested was that the two populations have identical distributions and the alternative was that the medians are different. The hypothesis is also viewed as the equality of the two medians. This test was used in a previous study on the effectiveness of deer warning reflectors.[4] Levels of significance of 0.05 and 0.1 were used.

RESULTS AND DISCUSSION

Selection of Sites and Reflector Installation

Initially, two sites were selected for this study. VDGIF staff and VDOT field crews responsible for deer carcass removal were consulted on the site selection and for additional participation in the study. VDGIF staff advised that other sites with more deer-vehicle collisions should be considered. As a consequence, local game wardens and VDOT staff in the Culpeper District were contacted to identify road sections with a high incidence of deer-vehicle collisions. Following screening of sites, VDOT staff and local game wardens conducted site reviews; exchanged information on activities around the site; assessed each site's potential for the study; and in some cases, recommended additional sites for consideration. Eight study sites were tentatively selected in the Culpeper District and one site was selected in York County. Later, all districts were invited to participate, and the Hampton Roads, Staunton, Lynchburg, and Fredericksburg districts offered sites. After the first series of installations (five sites in 2000), VDOT field staff was largely given the responsibility of selecting sites.

A site was selected to be a control or a reflector section based on the desire to have the two sections as alike as possible. VDOT and VDGIF staff were told of this intent and their input was sought in identifying the two sections. The adjacent sections yielded the same vehicular traffic volumes. Similar deer traffic was desired. If one of the sections had more deer-vehicle collisions, it was usually the reflector section. The experience and knowledge of the VDOT staff and the game warden were relied upon since data on carcass pickups were not available. The reported deer-vehicle accidents were reviewed as supplemental data.

Ultimately, deer warning reflectors were installed at 10 sites, as listed in Table 3, from October 2000 to May 2002. Five of these sites were in the Culpeper District. Three sites were on four-lane divided highways, I-64 ,and Route 29 with an AADT range of 15,000 to 36,000. Of the 7 two-lane sites, 6 were primary roads and 1 was a secondary road with an AADT range of 4,100 to 9,600. Six sites were at least 1 mile in length, three were ½ mile, and one was ¼ mile. John Strieter, President of Strieter-Lite Corporation, inspected all 10 sites to certify that the reflectors were properly installed. Except for site 10, a section on Route 205 in King George County, all of the control sections were adjacent to the reflector section. For site 10, because AHQ staff noted that the adjacent sections did not have the same level of deer carcass pickups, they suggested an alternate route to achieve similar conditions for potential deer-vehicle collisions.

Figures 3 through 5 display road sections of three sites where deer warning reflectors were installed.

Table 3. Description of Study and Control Sites

Site No.	Route	County	Description	Length (mi)	AADT	Installation Date
1	704	York	0.3 mi S of Route 238 to 1 mi N of Route 17	1.0	4,900	October 2000
1 control	704	York	Route 17 to 1 mi N of Route 17	1.0	4,900	
2	229	Culpeper	Route 211 to ½ mi S of Route 211	0.5	5,500	October 2000
2 control	229	Culpeper	½ mi S of Route 211 to Route 621	0.5	5,500	
3	29	Madison	Route 634 N to Route 29Business	1.0	15,000	October 2000
3 control	29	Madison	Route 634 S 1 mi	1.0	15,000	
4	15	Madison	Route 634 S 1 mi	1.02	4,300	October 2000
4 test	15	Madison	Route 634 S 1 mi to Great Run Bridge	0.27	4,300	April 2001
4 control	15	Madison	Great Run Bridge S 1 mi	1.0	4,300	
5	I-64	Albemarle	Route 782 to Route 781	0.45	36,000	December 2000
5 control	I-64	Albemarle	Route 29 to Route 782 and Route 781 to 5th St (1/4 mi each)	0.5	36,000	
6	175	Accomac	1.5 mi E of Route 798 to 2.1 mi E of Route 798 (0.6 mi) and 2.3 mi E of Route 798 to 2.7 mi E of Route 798 (0.4 mi)	1.0	6,200	May 2001
6 control	175	Accomac	0.8 mi E of Route 798 to 1.5 mi E of Route 798)	0.7	6,200	
7 control	275	Augusta	0.72 mi W of Route 11 to 0.99 W of Route 11	0.25	9,600	June 2001
7	275	Augusta	¼ mi on each side of the reflector section	0.5	9,600	
8	29	Albemarle	1 mi S of I-64 to 2 mi S of I-64	1.0	16,000	October 2001
8 control	29	Albemarle	2 mi S of I-64 to 3 mi S of I-64	1.0	16,000	October 2001
9	15	Buckingham	0.9 mi N of Route 617 to Route 692	0.5	4,500	April 2002
9 control	15	Buckingham	½ mi section N of reflector section	0.5	4,500	
10	205	King George	Route 620 to Route 617	1.42	4,100	May 2002
10 control	206	King George	Route 611 to Route 644	1.03	7,700	

AADT= average annual daily traffic

Figure 3. Deer Warning Reflectors on Route 15 in Madison County

Figure 4. Deer Warning Reflectors on Route 205 in King George County

Figure 5. Deer Warning Reflectors on Route 29 in Madison County

Data Analysis

Trend Analysis on Deer Carcass Pickups

Data were collected at 7 sites for 18 months or more and at 3 sites for 28 months. All sites have data from at least one deer-rutting (or mating) season, October-December, when deer-vehicle collisions are highest. The number of deer carcass pickups was normalized by using the number of carcass pickups per mile per year to account for the different section lengths and time period of data collection. The number of carcass pickups in the reflector section ranged from 0 to 11, with a mean and standard deviation of 4.6 and 3.6, respectively. Similarly, the number of carcass pickups in the control section ranged from 0 to 24, with a mean and standard deviation of 4.8 and 7.4, respectively. It is interesting to note that there were no deer carcass pickups at one reflector site, Route 275 (also the shortest reflector site at ¼ mi in length) and the three control sites (the last three sites in Table 4) with the shortest data-gathering periods.

Sometimes in trend analysis, a small difference in magnitude may yield a large percentage difference. For example, if one carcass pickup in a control site is compared to two carcass pickups in a reflector site, the difference of one carcass yields a 100 percent difference. Therefore, a practical difference is considered. *Practical difference* is arbitrarily defined as sites where the difference in the number of carcass pickups between the reflector and control sections is greater than 2 and the percentage is greater than 35, if it is defined. At three sites, there was no practical difference. At 5 sites, the reflectors sections had a greater number of pickups, and at 2 sites, the control sections had the greater number of pickups. Based on these observations, it

Table 4. Summary Data of Deer Carcass Pickups for Study Sites

Site	County	Months of data	Number of Miles	Control Carcasses/ mi/yr	Reflector Carcasses/ mi/yr	% Difference	Practical Difference
Route 704	York	28	1	2.1	4.7	124	+
Route 229	Culpeper	28	0.5	24	10.3	-57	-
Route 29	Madison	28	1	1.7	4.3	153	+
Route 15	Madison	21	1	2.3	2.2	-4	0
I-64	Albemarle	23	0.45	1	2.3	130	+
Route 175	Accomac	21	1	3.2	2.2	-31	0
Route 275	Augusta	18	0.25	13.3	0	-100	-
Route 29	Albemarle	12	1	0	2	undefined	0
Route 15	Buckingham	10	0.5	0	7.2	undefined	+
Route 205	King George	6	1.4	0	11.2	undefined	+
Mean		20	0.81	4.8	4.6	31	
Std. deviation		8	0.34	7.4	3.6	95	

Note: The means of the carcass pickups are based on data from all sites whereas the mean percent difference is based on the 7 sites where its value is defined.

appears that the reflectors were not effective in reducing deer-vehicle collisions at 8 of the 10 sites.

Figure 6 displays the difference in the number of deer carcass pickups between the reflector and control sections. The number in the control section for sites 2 and 7 stands out. At sites 1 and 3 through 6, the carcass pickup differences were minor. The absence of deer carcass pickups in reflector sections at sites 8 through 10 is also evident.

In Table 5, the deer-vehicle collision rates were calculated using the deer carcass pickup data. The statewide averages represent the collision rates for the interstate, primary, and secondary road systems based on the reported accident data in Table 1. Therefore, the last column was used more as a benchmark for reported accidents and not for direct comparison because the collision measures are different. The collision rates for both the control and test or reflector section were highest for the Route 229 site. As expected, the rates were lower where the volumes were highest.

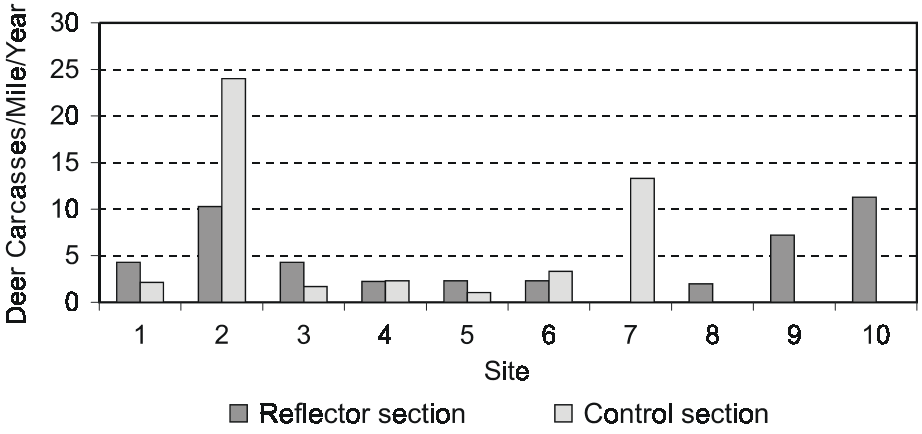

Figure 6. Deer Carcass Pickups for Reflector and Control Sections of Study Sites

Table 5. Deer-Vehicle Collision Rates

Site	AADT	Deer Collisions/mi/yr		Deer Collision Rate (coll/mvm)		
		Control	Reflector	Control	Reflector	Statewide Average
Route 704, York Co.	4,900	2.1	4.7	1.17	2.63	0.08
Route 229, Culpeper Co.	5,500	24	10.3	11.96	5.13	0.09
Route 29, Madison Co.	15,000	1.7	4.3	0.31	0.78	0.09
Route 15, Madison Co.	4,300	2.3	2.2	1.47	1.40	0.09
I-64, Albemarle Co.	36,000	1	2.3	0.08	0.18	0.03
Route 175, Accomac Co.	6,200	3.2	2.2	1.41	0.97	0.09
Route 275, Augusta Co.	9,600	13.3	0	3.79	0.00	0.09
Route 29, Albemarle Co.	16,000	0	2	0.00	0.34	0.09
Route 15, Buckingham Co.	4,500	0	7.2	0.00	4.38	0.09
Route 205, King George Co.	4,100	0	11.2	0.00	3.98	0.09

coll/mvm = collisions/million vehicle-miles.

Statistical Analysis of Deer Carcass Pickups

The two test groups (all sites and sites with more than 21 months of data) that were tested using the Wilcoxon rank sign test yielded the same result: that is, the null hypothesis that the medians of the reflector and control sites are equal was accepted. Thus, there is no statistically significant difference between the deer carcass pickups at the reflector sites and the control sites.

Experiment of Reflectors on One Side of the Road on Route 15

On a 0.27-mile section of Route 15 in Madison County, reflectors were installed on only one side of the road. The owner of the farmhouse across the road from the reflectors requested that reflectors not be placed in front of his house. He did not like their appearance and did not want to incur the additional maintenance effort required since he mows the state right of way in front of his property. The experimental section was between the standard reflector section with reflectors on both sides of the road to the north and the control section to the south. There was one deer carcass picked up in the experimental section during a 21-month period. However, when normalized to carcass pickups per mile per year, the number was similar to the control and reflector sections. It is interesting to note that the farmhouse owner perceived that the standard reflector section reduced deer-vehicle collisions on the roadway.

Cost Analysis

Installation Cost

The Culpeper District sign crew staff installed reflectors at half of the study sites. Their installation cost estimate for a two-lane highway was $13,600 per mile. The manufacturer of the reflectors estimated the service life to be 12.5 years. Thus, the cost of installation annualized over 12.5 years was $1,088.

Maintenance Cost

Maintenance costs consist of the sum of additional mowing costs attributed to the presence of the reflectors plus the cost to repair the reflectors. The added cost is credited to the need for hand mowing around the reflectors. Mowing costs at five sites are presented in Table 6. The range of the annual added cost for mowing around the reflectors was $852 to $1,768, or an annual average added cost of $1,147.

The costs to repair reflectors are shown in Table 7. Detailed records of repair activity are in Table A1 of the Appendix. Repair included straightening or replacing the posts, replacing reflectors, replacing hardware, or a combination of the three. Mean repair costs for all sites were $425, whereas the mean repair costs for only sites where repairs were made were $607. To be conservative, the higher value was chosen. The manufacturer estimated the annual maintenance cost to be $500 based on the experience of others and focused on repair not mowing costs. The average annual maintenance cost was $1,754**.**

Table 6. Mowing Costs for Reflector and Control Sections at Five Sites

Site	County	Control	Reflectors	Difference	% Difference	Contract or State	No. Times/Yr	Added Cost/mi/yr
Route 704	York	$255	$430	$175	69	State	6	$1050
Route 229	Culpeper	570	712	142	52	Contract	3	852
Route 29	Madison	552	994	442	78	Contract	4	1768
Route 15	Madison	105	437	332	316	Contract	3	996
Route 175	Accomac	86	236	150	174	State	5	1071
			Mean	248	138		Total	5737
			Std. deviation	133	110		Mean	1147
							Std. deviation	357

Table 7. Costs to Repair Reflectors

Site	Location	Months of Data	No. Miles	Total Repair Cost ($)	Repair Cost /mi/yr ($)
Route 704	York	28	1	0	0
Route 229	Culpeper	28	0.5	70	60
Route 29	Madison	28	1	1003	430
Route 15	Madison	21	1	2691	1538
I-64	Albemarle	23	0.45	1361	1578
Route 175	Accomac	21	1	0	0
Route 275	Augusta	18	0.25	26	69
Route 29	Albemarle	12	1	487	487
Route 15	Buckingham	10	0.5	0	0
Route 205	King George	6	1.4	59	84
Mean for all sites		20	0.81	569.7	425
Std. deviation		8	0.34	842.6	591
Mean for sites non-zero costs					607
Std. deviation for sites non-zero costs					623

Total Cost of Deer Reflector Road Section

Based on the information provided, the total annual per mile cost of the Strieter-Lite reflector is $2,842.

Deer-Vehicle Collision Costs

From Table 1, the cost of a deer-vehicle collision that involves property damage only (PDO) is estimated at $2,300. These estimates are based only on police reports not the actual costs. Since 91 percent of the deer-vehicle collisions are PDO, the use of PDO cost is appropriate to estimate the costs of these collisions. Strieter Corporation data put this cost at $2,500. Since the $2,300 is an estimate; the author chose $2,500 for this cost. In order for the benefits of the reflectors to exceed their installation and maintenance costs, the reflectors would have to prevent at least 1.14 deer-vehicle collisions per mile per year. Only two sites, Route 229 and 275, demonstrated a benefit, with the Route 175 site very close.

Residency Survey

Upon conclusion of the monitoring period, a questionnaire was emailed to the residency staff who monitored the study sites. The purpose of the survey was to confirm information on some of the site descriptions; obtain information on the level of maintenance and drive-through inspections of the sites; and obtain the opinions of the residency staff relative to the monitoring, maintenance, and performance of the reflectors. The results of the survey are presented in Table A2 of the Appendix. Nine of the 10 sites were checked by drive-throughs of the site at least weekly. The residency staff viewed the maintenance of the reflectors to be excellent at 7 sites and good at the remaining sites. There was an instance at 2 sites were a damaged reflector was in place for more than 7 days. There was no mention of changes that occurred during the monitoring that would influence the deer–vehicle collision activity. Seven respondents thought that the study sites were a good choice. Eight thought that the reflectors did not influence deer carcass pickups and recommended that the reflectors be removed. The primary reason for this assessment was the increased difficulty in mowing around the reflector posts. This finding is not surprising given that the monitoring staff's main responsibility is roadway maintenance and any device that makes maintenance more difficult is likely to be spurned. However, one residency group responded positively, stating that the reflectors worked in that no deer had been picked up at the reflector site. Another suggested that more data are needed.

DISCUSSION

Based on discussions with Mr. Strieter, the expected number of deer carcass pickups on road segments where deer warning reflectors are present is 0 to 2 per mile per year. Of the 10 sites studied, only sites on Route 275 and Route 29 in Albemarle County had this number of deer carcass pickups.

At several potential sites, there were concerns about the acceptance of the reflectors when they are placed in front of houses. A possible secondary road site was deleted after the property owner who was consulted about an installation disapproved of having the reflectors in front of his property. In one instance, a county board of supervisors requested that the reflectors be removed. One supervisor argued (1) that the reflectors created a safety problem by not allowing vehicles to pull over onto the shoulder and (2) that there were no problems with deer-vehicle collisions at the two reflector sites in their county. Mr. Strieter had not recalled a concern of this nature in other states where his product is used. In fact, he stated that in many cases residents have embraced the reflectors and assisted in their monitoring and maintenance.

Some reviewers of the study were concerned with the fact that the VDOT staff monitoring the study sites perceived the reflectors as making their mowing jobs more difficult or in the case of contract mowing, more expensive. One reviewer asked about assurances that the monitoring data were accurate. Another responded that in other cases, the reflectors were not successful when the DOT staff was not supportive of them. A third suggested that a third party should be responsible for monitoring the sites. There was no mechanism in place to verify the accuracy of the data, and there is no evidence to suggest that the VDOT field staff did not accurately provide the data. There is no guarantee that a third party would provide accurate data. It is noted that one of the reflector sites with a reduction in carcass pickups when compared to the control site was in a residency that would like all of the reflectors removed. Along this same line, one agency uses deer warning reflectors primarily to reduce the need for their maintenance staff to handle deer carcasses. The sight and smell of decaying carcasses make carcass pickup an unpleasant task. Thus, the prime use is to benefit the maintenance staff.

LIMITATIONS OF THE STUDY

Most studies of this nature are done as “before and after” studies at the same site. Sometimes control or comparison sections are used. Since “before” data on deer carcass pickups were not available, there was a choice to collect before data and then install the reflectors or use a cross-section study design and to compare the study site with a similar site for the before data. Since there was a sense of urgency to initiate this study, the latter method was selected.

An ideal study design would be one where the reflectors would be covered and uncovered for specific periods (such as monthly or biweekly) at a site. This method would provide continuity and consistency with respect to the deer crossing patterns and activity over time. Unfortunately, the resources for this labor-intensive method were not available. Even if the resources had been available, concerns about liability should a deer-vehicle collision occur when the reflectors were covered might have kept the researchers from pursuing the cover/uncover method.

Deer crossing activity patterns may change over time. There were no means available to measure or monitor either the size of the deer population in the vicinity of the study sites or their level of crossing activity. Moreover, deer crossing patterns in the experimental section could be slightly different from those in the adjacent control section. Therefore, any significant

differences in deer population or crossing patterns in the experimental or control sections are unknown.

The time of the deer-vehicle collision is unknown. Only the time of pickup, which usually occurred during daylight, is known. The overall deer pickups were compared without regard to time of day. Since about 80 percent of deer-vehicle collisions occur at dusk, dawn, or night, it is likely that the collision that resulted in a deer carcass pickup occurred at night.[7] Thus, it is assumed that the lower visibility at night is in large part a major factor in these nighttime collisions. There is a possibility that additional deer-vehicle collisions occurred but were not recorded because the deer was able to travel beyond the VDOT right of way and the immediate vicinity of the road. The deer may have died several hundred feet from the road or survived. Therefore, underreporting of deer-vehicle collisions based on carcass pickups is possible.

The reflectors were neither washed nor cleaned, as recommended by the manufacturer. Resources were not available for this activity, and this did not appear to be a problem. The author observed that at one site, many reflectors were covered with a white coating from salt and chemicals applied to the roadway for snow removal. Less than a week later, the rain cleaned the reflectors.

CONCLUSIONS

- There is no evidence that the deer warning reflectors were consistently effective across most sites.

- The experimental section with deer warning reflectors on one side of the road yielded results similar to those of the standard sections (reflectors on both side) and control sections.

- To recover the installation and maintenance cost or to make the benefits exceed the costs, the reflectors need to prevent more than 1.14 deer-vehicle collisions per mile per year.

RECOMMENDATIONS

1. *VDOT should expand deer warning reflector coverage to the control sections on Route 229 and Route 275 and monitor deer carcass pickups at those sites through December 2004.* The Route 175 site may also be a candidate for expanding the deer reflector coverage.

2. *VDOT district and residency staff should decide whether to retain, modify, or remove deer warning reflectors at the remaining seven sites since there is little conclusive evidence that the reflectors are having any effect on deer-vehicle collisions.* The author should meet with the appropriate staff to assist in making those determinations.

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APPENDIX

Figure A1. DEER WARNING REFLECTOR DATA COLLECTION FORM

Site:	**Month and Year:**

Name and Phone Number:

Activity	**Date**	**Time**	**Location** (see below for a description)	**Cost**

Activity: Deer Carcass Pick up/Deer Put Downs/Deer-Vehicle Accident Reports/Description of Damage to the Reflectors and Posts and when detected/ Repair of damaged reflectors and posts. These are typical activities; please describe other activities as necessary. Please include any maintenance activity such as mowing or spraying that may be affected by the presence of the reflectors. The additional maintenance costs due to the reflectors is important.

Location: Include nearest reflector ID number on post. For locations without reflector posts, include the distance from the nearest reflector with its ID number or measure from another landmark (such as an intersection) and the side of the road).

Attach (or describe on the back) any comments from residents and the community.

Table A1. Maintenance Activity and Costs for Deer Warning Reflectors

Site (County)	Date	Replaced Poles	Straightened Poles	Replaced Hardware	Replaced Reflectors	Subtotal Cost	Labor	Equip.	Total	Cause of Damage
Rte 29 S (Alb.)	05/02/2001	$10	$0	$6	$16	$32	$8		$40	SB lane accident
Rte 29 S (Alb.)	05/31/2001	20	70	6	16	$112	$30		$142	contract mowing
Rte 29 N (Alb.)	09/12/2002		230	15	49	$294	$10		$304	unknown
							Grand Total		**$487**	
I-64 W (Alb.)	05/21/2001	20	30	6	66	$122	$32		$154	contract mowing
I-64 W (Alb.)	05/22/2001	10	60	6	16	$92	$10		$102	contract mowing
I-64 W (Alb.)	05/23/2001	30	100	3	16	$149	$37		$186	contract mowing
I-64 W (Alb.)	05/24/2001	10	60	6	16	$92	$7		$99	contract mowing
I-64 W (Alb.)	05/25/2001	10	10	1		$21	$8		$29	contract mowing
I-64 W (Alb.)	06/15/2001		60	1	33	$94	$5		$99	contract mowing
I-64 W (Alb.)	06/18/2001	20	150	11		$181	$30		$211	contract mowing
I-64 W (Alb.)	08/15/2001	10		8	17	$35	$25	$5	$65	contract mowing
I-64 W (Alb.)	10/24/2001		50	7	16	$73	$6		$79	contract mowing
I-64 W (Alb.)	08/29/2002	40	110	24	102	$276	$60		$336	unknown
							Grand Total		**$1,361**	
Rte 29 (Mad.)	10/05/2000					$0	$5	$2	$7	contract mowing (straighten post)
Rte 29 (Mad.)	10/05/2000					$0	$5	$2	$7	contract mowing (straighten post)
Rte 29 (Mad.)	10/06/2000					$0	$5	$2	$7	contract mowing (straighten post)
Rte 29 (Mad.)	12/22/2000	30		23	49	$102	$21		$123	vehicle accident
Rte 29 (Mad.)	06/11/2001	40	70	6	66	$182	$56		$238	contract mowing
Rte 29 (Mad.)	05/28/2002	20	90	18	49	$177	$50		$227	unknown
Rte 29 (Mad.)	05/29/2002		30	12	66	$108	$40		$148	unknown
Rte 29 (Mad.)	06/20/2002	70		51	66	$187	$60		$247	unknown
							Grand Total		**$1,003**	

Site (County)	Date	Replaced Poles	Straightened Poles	Replaced Hardware	Replaced Reflectors	Subtotal Cost	Labor	Equip.	Total	Cause of Damage
Rte 229 (Culp.)	07/16/2001	10				$10	$60		**$70**	unknown
Rte 15 (Mad.)	10/03/2000	20		2	66	$88	$75	$15	$178	
Rte 15 (Mad.)	10/10/2000	20		2	33	$55	$40	$4	$99	
Rte 15 (Mad.)	10/20/2000			2	66	$68	$125	$20	$213	
Rte 15 (Mad.)	05/04/2001	10		7	33	$50	$21		$71	accident
Rte 15 (Mad.)	08/14/2001	20		2	16	$38	$10	$8	$56	
Rte 15 (Mad.)	10/03/2001	100		30	98	$228	$100		$328	contract mowing
Rte 15 (Mad.)	04/22/2002	30		9	33	$72	$0	$70	$142	pavement widening
Rte 15 (Mad.)	04/23/2002		190		16	$206	$0		$206	pavement widening
Rte 15 (Mad.)	05/30/2002	90	170	66	262	$588	$90		$678	contract mowing
Rte 15 (Mad.)	05/31/2002	90	90	66	295	$541	$180		$721	contract mowing
								Grand Total	**$2,691**	
Rte 205 (King Geo.)	08/16/2002	10		6	33	$49	$10		**$59**	accident
Rte 275 (Aug.)	05/23/2002				16	$16	$10		**$26**	contract mowing
Total				**$402**	**$1,626**	**$4,338**	**$1,231**	**$128**	**$5,696**	

Table A2. Post Data Monitoring Deer Warning Reflector Questionnaire

1. Deer Warning Reflector location: Route: County:

2. Briefly and in general terms, describe the land use on both sides of the reflector and control sites.

3. Are the deer crossing activities similar in these two sections? _10__Yes ___No. If no, how are they different?

4. On average, how frequently did you or your crew check the reflectors by driving through study section? _6__Daily _3__Weekly _1_other(biweekly):

5. How well were the reflectors maintained (that is, kept in their initial position)? _7_Excellent _3_Good ___Fair ___Poor.

6. Were there any cases where the reflectors were missing or damaged for more than 7 days? _2_Yes _8_No. If yes, please provide the dates when this condition existed if available.

7. In your opinion, has the deer warning reflectors reduced the number of deer carcass pickups based on the experience before the reflectors were installed? _2_Yes _8_No ___I don't know.

8. Did any changes occur during the monitoring period that may have influenced the number of deer carcasses picked up? ___Yes _10_No. If yes, please describe the change. Changes may include new construction, wooded areas being cleared, etc.

9. In your opinion, was this a good site for deer warning reflectors? _9_Yes _1_No. If no, explain why. A higher volume location desired.

10. What would you like to see happen to the deer warning reflectors at this site? _2_Nothing _8_Remove them ___Expand the section (explain where); ___Other (describe).

11. Please provide any comments.
    The reflectors make it hard and costly to mow. 4
    The reflectors are not effective.
    More data are needed.
    In the reflector area deer are accustomed to the reflectors and people.
    They work. No deer have been struck in the reflector area. (Route 275 is the only site where this is true.)