Wildlife Damage Management Fact Sheet Series

Reducing Deer-Vehicle Crashes

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Background

Many motorists and communities across North America are increasingly concerned about deer-vehicle crashes (DVCs). More than 1.5 million DVCs occurred in the United States in 2002, causing at least $1.1 billion in vehicle damage and killing about 150 humans and at least 1.5 million deer. These numbers are rising every year with the continued increase in both deer numbers and motor vehicle traffic.

Although many methods have been implemented in an attempt to reduce DVCs, few have been well documented or evaluated. This fact sheet reviews crash prevention methods and evidence of their effectiveness. We make recommendations for data collection and reporting that, if implemented, would help define the problem more precisely and evaluate DVC control methods more accurately.

Current Deer Population and DVC Statistics

It is difficult to estimate numbers of deer, but there is clear evidence that populations have increased over the past century, especially over the last three decades. Deer numbers nationwide were estimated at about 2 million in 1900 and at 16 to 17 million by the mid-1990s. Other estimates placed the total U.S. deer population at 25 to 30 million by the end of the twentieth century. In New York, there were only about 20,000 deer in the early 1900s but about 1 million in the late 1990s.

The number of DVCs that occur nationwide is also difficult to estimate, but evidence indicates that they are increasing. Most states record vehicle crashes involving animals but do not distinguish deer from other species such as moose, elk, horses, and cattle. The National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System, a census of all fatal traffic crashes, shows an average of 111 fatal crashes involving animals between 1992 and 1995 and approximately 154 between 1998 and 2001, a 39 percent increase. NHTSA's General Estimates System estimates about 222,000 police-reported crashes with animals annually in 1992–93 and 274,000 in 2000–2001, a 24 percent increase.

DVC data from states that do distinguish deer from other animals suggest that most animal crashes involve deer: 99.7 percent in Michigan, more than 90 percent in Minnesota, and 93 percent in Pennsylvania. DVCs increased by 54 percent in Pennsylvania from 1994 to 2000, by 51 percent in Iowa from 1990 to 1997, and by 69 percent in five states combined (Illinois, Maine, Michigan, Minnesota, and Utah) from 1985 to 1991.

Many people do not report DVCs to police. A 1990 telephone survey of homeowners in New York indicated that police were notified of about half, and insurance companies of less than half, of DVCs. Taking the underreporting to police into account, it was estimated that about 1.5 million DVCs occurred nationwide each year in the mid-1990s. In 2000, an estimated 131,500 DVCs occurred in Illinois, Iowa, Michigan, Minnesota, and Wisconsin combined, causing 23 deaths, 4,650 injuries, and $222 million in vehicle damage.

DVCs are seasonal: those involving white-tailed deer peak in October and November during the breeding season, and a secondary peak occurs in May and June as yearling deer disperse from their birth areas. DVCs with mule deer are most frequent during the spring and fall migrations. DVCs occur predominantly in darkness, on high-speed, two-lane, rural roads, especially when forest cover is close to the roadway.

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Synthesis of Existing Information

We have summarized published studies and other information obtained from highway safety, motor vehicle insurance, and natural resources sources. Three review studies were especially useful: Danielson and Hubbard (1998), DeerCrash (2003), and Putman (1997). The DeerCrash web site (www.DeerCrash.com) contains an extensive bibliography and is updated periodically with summaries of information on specific methods.

Three general strategies to reduce DVCs are to modify driver behavior, modify deer behavior, or reduce the number of deer. We summarized the supporting evidence for each method based on the available research. More emphasis was given to methods for which there was evidence from studies with sound designs, controls for potentially confounding influences, adequate sample sizes, and consideration of how the method's effectiveness may change over time.

Modifying Driver Behavior

Awareness of Deer

General education efforts provide information about the dangers of DVCs so that drivers will watch more carefully for deer. Methods include news stories and public awareness campaigns in peak DVC seasons. About half of U.S. states use some form of general education, but none of these campaigns has been evaluated. Campaigns can be effective when they present new information that directly affects drivers and is reinforced by something drivers can observe. General education about DVCs is unlikely to be useful unless it provides information on very specific and time-sensitive situations, such as the beginning of mule deer migration across a short road segment. In these situations, either temporary passive or active signs may be more effective than general campaigns.

Signs

Roadside signs attempt to warn drivers of specific locations and even times when deer may be present. Passive signs have a fixed message at all times, though they may use lights or animation to attract attention. Active signs are lighted when deer are detected on or near the roadway.

Roadway signs warning drivers of deer-crossing locations are widely placed. Nearly all are passive: fixed signs in fixed locations, with the same message in words or pictures at all times and in all seasons. Most use a standard yellow diamond sign with the figure of a deer, as specified in the *Manual of Uniform Traffic Control Devices.* No studies have evaluated the effectiveness of standard deer warning signs in increasing driver awareness of deer, in reducing driving speeds, or in reducing DVCs. Because passive signs are used so frequently at locations where deer are present only occasionally, drivers may ignore them.

Several methods have been used to increase the effectiveness of deer warning signs. The first is to make the signs more visible with lights, flags, or even a lighted and animated figure of a deer. A study of lighted and animated signs found a slight effect on vehicle speeds but no effect on numbers of DVCs. The second method, used on roads crossed by mule deer migration corridors, was the installation or uncovering of passive signs only during migration periods. Large warning signs with battery-powered flashing amber lights were used at the ends of a 2-mile (3.2 km) and a 4-mile (6.4 km) roadway section, together with smaller flashing signs at each milepost within the two sections. Travel speeds dropped about 8 mph (12.8 km/hour) from pre-migration levels during three deer migration periods when the signs were displayed and activated. DVCs dropped by 50 percent in the spring and 70 percent in the fall migration compared with three previous years. In a more extensive study of the same technique, temporary lighted signs were placed on five roadway sections in three states with an adjacent section as a control. DVCs were about 50 percent lower in signed than in control sections across all sites.

Active signs are activated only when deer are detected near the roadway. Detection methods include infrared light (Minnesota), radar (Wyoming), laser (Washington), radio frequency beams parallel to the roadway (Indiana), and heat detection cameras (British Columbia). In Washington, radio collars have been attached to eight elk in a herd of 80 near a segment of Highway 101. Flashing "elk warning" signs are activated when any of the collared elk come within one-quarter mile (0.4 km) of the roadway. The only evaluation of these methods to date is a small study of a segment of U.S. 30 in Wyoming. An 8-foot (2.46 m) fence was erected along both sides of the roadway, with a 300-foot (92 m) gap through which migrating mule deer could cross. Two deer detection systems were used: infrared heat sensors and geophones that detect ground vibrations combined with infrared light beams that detect motion across the beam. Both systems detected almost all deer. Vehicle speeds dropped by about 4 mph (6.4 km/hr) when the "deer on road when lights are flashing" sign was lighted, regardless of whether the sign was triggered by a deer, a false positive, or remotely by a researcher. DVC data were not collected, and it is unclear whether the observed speed reduction would be large enough to affect DVCs.

In summary, standard passive signs are unlikely to have any effect. The one study of lighted signs showed no effect on DVCs. Initial results are encouraging for temporary passive signs used in defined mule deer migratory corridors during migratory periods.

Visibility of Deer

The sooner a driver sees a deer on or approaching a roadway, the better the chance of avoiding a crash. Visibility of deer can be improved through roadway lighting, clearing of roadsides, or enhancement of drivers' nighttime vision.

Roadway lighting is commonly used to improve drivers' vision in urban areas, on freeway interchanges, and in other potentially dangerous locations. Because most DVCs occur at night, roadway lighting is an obvious potential countermeasure. In the only study of the effect of roadway lighting on DVCs, however, lighting did not affect overall numbers of deer crossings or driving speed, and the study was too small to detect an effect on DVCs. Only two states reported using lighting to control DVCs, and it is unlikely to be useful except in very specialized situations such as a heavily traveled road that crosses a mule deer migration route.

A broad, clear roadside allows drivers to see deer that may enter the road, and the absence of forage may prevent some deer from approaching the roadway. The most important landscape or topographical feature predicting high DVC sites in Illinois was the distance between the roadway and forest cover. In a study in Norway, a clear 65- to 98-foot (20 to 30 m) wide strip reduced crashes between railway trains and moose by more than 50 percent. Roadside clearing raises many issues beyond DVC control, such as the costs of acquiring roadside right-of-way and of maintaining a clear area, the potential safety benefits if trees adjacent to the roadway are removed, and the aesthetics of cleared areas along secondary roads.

A potential long-term strategy to improve drivers' night vision is to equip vehicles with infrared technology that can detect deer and other heat-emitting objects and transmit information to drivers on heads-up displays. These systems have been introduced recently in Cadillacs and as aftermarket equipment for trucks, but their effects on DVCs have not been evaluated. Any strategy involving vehicle modifications requires many years to implement in the majority of the vehicle fleet.

Speed Limits

Reducing travel speeds by lowering speed limits is often suggested as a way to reduce vehicle crashes. Unfortunately, lower speed limits do not necessarily produce lower travel speeds. The only study that evaluated the effects of speed limit changes on crashes with wildlife involved short road segments in the highly regulated environment of Jasper National Park in Alberta, Canada. Sheep and elk crashes were compared for eight years before and eight years after the speed limit was reduced from 53 to 43 mph (90 to 70 km/hr) on three short highway segments. The results were inconclusive. Sheep crashes increased on these segments and decreased on adjoining segments where the speed limit remained 90 km per hour. Elk crashes increased on both the highway with the reduced speed limit and the unchanged highway segments.

Speed limit reductions together with deer warning signs may be useful in very specific locations that have high deer populations or are migration routes. However, unless speed limits are actively enforced, they are unlikely to affect travel speeds significantly and perhaps not even then. Although seven states reported reducing speed limits in an attempt to control DVCs, the effects of these speed limit reductions have not been evaluated.

Modifying Deer Behavior

Physical Control

The purpose of fencing is to physically prevent deer from entering a roadway. Every review of DVC control methods during the past 20 years has concluded that properly designed and maintained fencing, used together with appropriate underpasses, overpasses, and one-way deer gates, is the most effective method for reducing DVCs both in the United States and in Europe. State wildlife administrators agree, while state highway administrators rank fencing second to reducing deer herd size. In 1992, 11 states had erected fencing to reduce DVCs.

Aside from herd reduction, fencing is the only DVC prevention method that unquestionably is effective if applied properly. Fencing that is sufficiently high, strong, long, and well-anchored with no gaps or tunnels will prevent deer from crossing a road section. The issues with fencing involve the details and side effects.

Physical characteristics. Fencing must be sufficiently high and long to deter deer. Several studies have found 7.8 ft. (2.4 m) fencing to be effective, but white-tailed deer will jump a 7.4 ft. (2.2 m) fence in search of food. Fencing must extend far enough along a roadway to discourage deer from detouring around the ends of the fenced section. The necessary length depends on deer movement patterns.

Maintenance. Regular checks are required to repair tunnels and breaks caused by erosion, animals, falling trees, and people. Deer test fences regularly and will quickly pass through any breaks or gaps. Deer can crawl through openings less than 10 inches (20.4 cm) high under a fence.

Effect on deer movements. Fencing design should consider deer movement patterns and provide safe passage routes, as appropriate, through underpasses or other devices.

Escape routes. Deer that manage to enter a fenced roadway need a way to escape. One-way gates generally have proven successful.

Costs. Effective fencing is expensive to construct and maintain. The state of Iowa recently estimated construction costs for an 8-foot (2.46 m) chain-link fence on one side of a roadway at $42,000 per mile ($26,087/km).

Other effects. Roadway fencing or more substantial physical barriers may have additional benefits such as reducing noise in adjacent properties or preventing pedestrian access to high-speed roads. Fencing and barriers may have positive or negative aesthetic implications.

Underpasses and more rarely used overpasses allow deer to cross a roadway without encountering vehicles. Deer sometimes use underpasses or overpasses created when highways cross rivers or tunnel through ridges. Seven states report using underpasses specifically to allow deer to cross. To be effective, fencing or other barriers must channel deer to underpasses and overpasses.

A system of fencing and six underpasses was used along 7.8 miles (12.6 km) of interstate highway crossing a mule deer migration route. The system did not disrupt deer movement and virtually eliminated DVCs. Other studies consider whether and how underpasses and overpasses are used rather than how they affect DVCs. Deer can be reluctant to use them, even when they are highly motivated to move along a migration route or to forage. Deer can remain wary or frightened even after several years of experience with the same underpass. Placing forage in underpasses may attract deer.

Factors affecting the use of underpasses and overpasses include their locations in relation to natural deer paths, size (wide openings and short lengths), design (earth floors), visual appearance (exit clearly visible from entrance, light walls and ceiling), and woody cover at the entrances. A minimum acceptable underpass "openness factor" of entrance area divided by underpass length seems important. Underpasses and overpasses are expensive when included in original highway construction; adding them to an existing highway is even more expensive.

At-grade crosswalks may provide a middle ground between a fully separated underpass or overpass and uncontrolled crossings marked only with signs. Nine crosswalks were installed on about 13 miles (20.9 km) of two-lane and 4 miles (6.4 km) of divided four-lane highways in Utah, with similar adjacent roads used as controls. At each crosswalk, fencing and landscaping directed deer to the crosswalk area. Because fencing was not permitted on the highway shoulder, the deer were channeled to the highway on a dirt path bordered by cobblestones. A similar path bordered by cobblestones crossed the divided highway's median strip. White-painted cattleguard lines bounded the path across the highway surface. One-way gates in the fencing near the crosswalks allowed deer that moved beyond the crosswalk area to leave the roadway. Passive signs warned drivers to expect deer in the crosswalk areas.

The crosswalks appeared to decrease DVCs by about 40 percent, although the small sample size precluded any definitive conclusions. The crosswalk design of cobblestones and cattleguard stripes directed many, but not all, deer across the road as intended. Although drivers may have been more alert for deer at crosswalk areas, fewer than 5 percent responded to crosswalk signs by slowing down or turning on their high-beam headlights. Crosswalks may be worth additional study to determine if design improvements can contain deer more effectively and if active signs that detect deer in the crosswalk area can improve driver awareness and actions.

Crosswalks, underpasses, and overpasses are more likely to be effective for western mule deer than eastern whitetails. Mule deer have defined migratory routes across highways, so DVCs are confined to relatively few locations where these expensive control methods can be justified. In contrast, crashes with white-tailed deer occur throughout substantial lengths of two-lane, rural roads. Further, DVCs occur most frequently in the fall breeding season, when antlered males are chasing females. At these times, crosswalks or other methods short of the complete physical control provided by substantial fences are unlikely to keep deer off the highway.

Sensory Control

Reflectors. The most contentious DVC control method is reflectors, which have been used in Europe and some areas of the United States for more than 30 years. Reflectors have both strong advocates and opponents, and results from more than 10 studies conflict. The most commonly used and most frequently evaluated system, manufactured by Swareflex, consists of reflectors installed on posts at regular intervals along the roadway. Headlights are reflected to form a continuous "visual fence" of red, blue-green, or white light that deer are expected not to cross. Red reflectors form a visual barrier that humans cannot detect, so that it does not distract drivers. In 1992, 22 states reported using reflectors.

The basic behavioral questions about reflectors are whether deer can see light in the wavelengths used, whether deer are reluctant to cross such light beams, and whether deer become habituated to light beams over time. Red and white light from Swareflex reflectors had no effect on penned white-tailed deer; the blue-green light was not tested. Fallow deer in a large forested area were exposed to light from WEGU reflectors (a design similar to Swareflex) during a period of 15 nights. The deer quickly became habituated to the reflected light: on the first night, 99 percent of the deer fled from low-intensity reflected light, while on the final three nights about 40 percent were completely indifferent to higher-intensity light.

DeerCrash.com describes and summarizes 10 studies that attempt to evaluate the effect of roadside reflectors on DVCs using different study designs. The overall results are ambiguous at best.

- Four studies used designs that alternately cover and uncover the reflectors along a roadway segment. One found reflectors effective and three did not.
- Four studies used before/after designs. One found reflectors effective, one did not, and two had inconclusive results.
- Two studies used treatment/control designs. One found that reflectors were effective at some sites but not at others and the other study found no effect.

The best study in terms of design, size, and power was a cover/uncover design with control segments used for three years on a 15-mile (24.1 km) segment of U.S. 30 in Wyoming. This road crosses a major mule deer migration route. A total of 126 DVCs were recorded when the reflectors were uncovered, 64 when covered, and 147 on control segments. It was concluded that the reflectors had no effect on DVCs.

The most positive site-specific evidence of effectiveness was found on four roadway sections totaling 2.3 miles (3.68 km) in Washington during three years, in an area populated largely by white-tailed deer. Again, a cover/uncover design was used, but with no control segments. Fifty-two DVCs were recorded when reflectors were covered and only six when uncovered, demonstrating that the reflectors were highly effective.

In Minnesota, reflectors were installed at 16 road segments totaling 16.35 miles (26.3 km), four segments each in coniferous forest, prairie farmland, central hardwood, and metropolitan hardwood habitats. Average annual DVCs were tallied on these segments for several years before and seven years after installation. There was a 79 to 90 percent reduction in DVCs in the three rural habitats from pre-installation DVC averages. In the metropolitan habitat, DVCs increased from a pre-installation average of 11.8 to 22.1 crashes per year following installation.

These three examples illustrate the difficulties of drawing definitive conclusions from even the best reflector studies. The increase in DVCs in metropolitan areas of Minnesota for road segments with reflectors may be a result of small sample sizes, increases in traffic volume, or ineffectiveness of reflectors on heavily traveled roads. If reflectors are effective, they offer obvious advantages. They are cheaper to install and maintain than physical barriers created with fencing and underpasses, though their cost is not insignificant—an estimated $8,000 to $10,000 per mile (ca. $5,000 to $6,000 per km), plus annual maintenance to repair or replace damaged reflectors. Reflectors form a barrier only when vehicle headlights are present, so they allow deer to cross roads freely during daylight hours. Direct observations of deer behavior suggest that deer quickly become habituated to the light from reflectors.

An early attempt to influence deer behavior through sight was based on the observation that white-tailed deer raise their tails as a warning sign to other deer. Rear-view silhouette models of deer with raised tails did not affect deer movements along a highway.

Whistles. Deer warning whistles have been available to the public for more than 20 years. A typical whistle is attached to a vehicle and produces ultrasonic noise in the range of 16 to 20 kHz when vehicle speed exceeds about 30 mph (48.3 km/hr). Whistles are based on the presumption that deer can hear and will be warned away from noise in this range. Twenty states reported using whistles in 1992, although state wildlife agency and transportation department administrators ranked whistles the least effective of common methods.

In a high-quality study of whistle effects on deer, investigators drove past

150 groups of deer at distances up to 325 feet (100 m) and speeds of 40.4 mph (65 km/hr), observing deer behavioral responses. Two common brands of whistles had no effect on deer behavior, even when deer were within 32.5 feet (10 m) of the road. There is no other research evidence that deer are frightened by sound in the range produced by whistles. Several less scientific reports and considerable anecdotal evidence either support or deny the effectiveness of whistles.

In summary, there is no firm evidence that whistles are effective and considerable evidence that they are not. It is unclear whether deer can hear whistles, whether whistle noise is covered by traffic noise, or whether deer become accustomed to whistle noise over time. In the absence of any solid studies that whistles are effective, they cannot be recommended.

Repellents. Several studies have evaluated the effectiveness of various repellents on the feeding patterns of white-tailed and mule deer. Some repellents reduced feeding, but none completely stopped deer from feeding or entering an area. The studies also showed that deer habituate to repellents and will not be deterred by them if sufficiently hungry. No study in the United States has evaluated the effects of repellents in reducing DVCs, and repellents are not used systematically in any state to control DVCs.

Feeding stations. In certain locations, deer regularly cross roadways to feed. In Utah, feeding stations were established and maintained more than 1,200 feet (369 m) from a roadway. Lower DVC counts were recorded in some, but not all, road segments with feeding areas. Such a feeding program has continuing costs, may make deer dependent on the food provided, and may attract more deer to the roadside. Intercept feeding may be useful only temporarily in specific situations.

Some authors suggest that deer may be attracted to roadways by salt applied to melt ice in the winter and that other deicing substances should be used instead. However, no studies have investigated the issue.

Reducing the Number of Deer

Reduction of deer herds has long been considered an appropriate strategy for reducing DVCs. State transportation department administrators rated herd management as potentially the most effective DVC control strategy, while state wildlife administrators rated it second only to fencing.

The only herd reduction strategy that would stop all DVCs would be to eliminate all deer, which the public would not accept. In a survey of 10 randomly selected large metropolitan areas conducted in the mid-1990s, 63 percent of respondents wanted no change in the number of deer in their neighborhoods, 27 percent wanted more deer, and only 10 percent wanted fewer deer.

Two reports document how local deer herd management policies can affect DVCs. After Princeton, New Jersey, passed a no-firearms-discharge ordinance in 1972, DVCs increased by 436 percent in 10 years, compared with no statistically significant change in two adjoining townships where deer hunting using firearms continued to be allowed. Princeton town officials then tried to reduce DVCs and other deer-related problems using whistles, reflectors, and increased bowhunting, but DVCs continued to rise, to 167 in 1991 and 227 in 1992. In Irondequoit, New York, a selective deer culling and bowhunting program was initiated in 1993. About 125 deer were removed in each of the next eight years. DVCs dropped from 227 in 1992 to about 100 annually in the late 1990s.

Although herd reduction can be controversial, common sense and expert opinion agree that substantial and continued herd reductions will reduce DVCs. However, many questions remain, including the effectiveness of widespread herd reductions on DVCs, the amount of herd reduction necessary to reduce DVCs substantially, how deer movements and migration patterns influence the effect of herd reductions on DVCs, and how to design cost-effective herd reduction programs. Wisconsin and other states are pursuing aggressive deer herd reduction programs, and data obtained may help address these questions.

Summary

Effective Methods with Solid Scientific Evidence

Fencing, combined with underpasses and overpasses as appropriate, is the only broadly accepted method that is theoretically sound and proven to be effective. Fencing is expensive to construct and maintain, and even the best fencing will not prevent all deer from entering a roadway.

Promising Methods for Which More Information Is Needed

Herd reduction is unquestionably effective in reducing DVCs if the deer population in a specific area is reduced by a substantial amount. More research is needed on the minimum area needed for herd reduction to have a substantial effect, and on the expected impact of a given amount of herd reduction on DVCs. A herd reduction strategy should be part of an overall wildlife management program that balances the costs and benefits of maintaining wildlife populations.

Both temporary passive signs and active signs appear promising in specific situations, but considerable research is required to evaluate long-term driver response and to improve and test deer detection technology for active signs.

At-grade crossings for deer, perhaps combined with active signs, offer a long-shot chance at providing greater safety than uncontrolled crossings marked only with passive signs. At-grade crossings are most promising for highways crossing mule deer migration routes in western states.

Methods with Limited Demonstrated Effectiveness

Although reflectors have been evaluated often, most studies were not well designed or conducted. The balance of the available evidence is that reflectors have little long-term effect, especially for white-tailed deer in suburban areas. Additional high-quality studies would be useful to investigate deer response and habituation to light beams and the effectiveness of reflectors when implemented.

Roadside lighting and intercept feeding may have limited effectiveness in specialized situations. Both methods are costly and have side effects that must be considered carefully.

Methods That Appear Ineffective Based on Available Evidence

General education, passive signs, and lower speed limits appear ineffective in influencing driver behavior and reducing DVCs. The lack of good studies proving their ineffectiveness probably results from the unwillingness of funding organizations to allocate resources to study methods that are so unpromising. Deer whistles and deer flagging signs are not effective.

Recommendations

There is no quick, cheap method to reduce DVCs. Fencing and herd reduction programs can be effective if they are well designed and maintained. DVC control must be part of an overall strategy that balances the competing needs of humans and wildlife. For example, there is a trend in suburban areas to preserve or create green space and wildlife corridors. These areas must be carefully planned and coordinated by transportation, natural resource, and urban planning agencies to avoid attracting more deer and increasing DVCs.

Data Collection and Reporting

States should identify crashes involving deer on their state crash report forms and crash data files rather than aggregating crashes involving all animals. Without this information, it is difficult to track DVC totals, trends, and patterns. States also should record precise DVC locations using GIS or other methods to identify areas with high DVC frequencies. This information is critical in deciding where fencing, herd reduction, active signs, or other DVC control methods are needed.

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