DEER-VEHICLE CRASH, ECOLOGICAL, AND ECONOMIC IMPACTS OF REDUCED ROADSIDE MOWING - FINAL REPORT

Prepared for
The Federal Highway Administration
1200 New Jersey Avenue, SE
Washington, D.C. 205909

Prepared by
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Bedford, NH 03110

R-19977.003

May 2012

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

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EXECUTIVE SUMMARY

This investigation was conducted as part of the Deer-Vehicle Crash, Ecological and Economic Impacts of Reduced Roadside Mowing project (EV0104). The primary goal of this project was to learn more about potential safety, ecological, and economic impacts of reduced roadside mowing, to identify and describe roadside vegetation management policies currently in place throughout the United States, and to quantify DVC impacts of reduced roadside mowing.

To meet the primary goal of this project, the investigation was broken into three primary tasks:

- **Literature review:** Current literature was reviewed and summarized to describe the potential safety, economic, and ecological impacts of roadside vegetation management policies and practices, including reduced roadside mowing.
- **Current and "Best" Practice Survey:** A survey of 24 different DOTs was conducted to identify and describe roadside vegetation management policies currently in place throughout the United States, and to determine if the policies used by the pooled fund member states were a typical representation of those used throughout the country. For states that had a reduced mowing program, the differences between their “typical" and "reduced" roadside mowing practices were identified. Any discussions of DVC or AVC impacts considered within these policies were also noted.
- **Quantify DVC Impacts of Reduced Roadside Mowing:** The potential safety impacts of reduced roadside mowing were quantified using existing data sets from two states. An experimental design report describes the methodology developed to evaluate the differences in DVC rates between “standard” mow and reduced mow regimes, and the results.

Results of the literature review, a survey of current roadside vegetation management practices and efforts to quantify DVC impacts of reduced roadside mowing are summarized below. Based on our literature review, the vast majority of roadside vegetation best management practices and recommendations address improved safety, promotion of drainage, control of noxious and nuisance weeds, and promotion of desirable natural vegetation. One of the highest priorities for mowing near roadways is to maintain sight distance so motorists can observe and avoid other vehicles, animals or pedestrians, and to be able to read road signs. Best management practices and recommendations specifically addressing deer and other wildlife, based on results from this literature review, are comparatively rare and largely limited to two categories: (1) restricting the timing of mowing to protect ground nesting birds, and (2) selection of plants to revegetate roadsides that are less likely to attract large animals which may cause potential safety hazards to motorists.

A reduction in roadside vegetation mowing has occurred throughout a majority of the United States in recent years based on results from our survey of 24 DOTs. Twenty-one of 24 states (88%) that responded to the survey reported a reduction in their mowing programs. For those 21 states that reduced mowing, 17 did so statewide while 4 reduced mowing in only some parts of their state. The timing of when roadside mowing programs were reduced varied from 1968 to 2010; however, nearly two-thirds (13/21=62%) of the states that had reduced mowing programs made their reductions in the past three years (2008-2010); 81% (17/21) in the past 7 years (2004-2010). Economic concern was the overwhelming reason provided why roadside mowing programs have been reduced in surveyed states with ecological concern being secondary. Ecological concerns included impacts of survival of ground nesting birds, establishment of native plants, and weed control. The nine pooled fund member states appear to be comparable to the rest of the country with regard to reduced mowing policies.

The final task of our investigation was to determine if reducing roadside mowing causes a measurable change (increase or decrease) in DVCs. A common perception is that decreased mowing may change vegetation structure which could affect deer density and/or behavior at the roadside, or motorists' ability to detect and react to deer entering the roadway. Both of these effects would be expected to increase the DVC rate. However, the results of a literature review and survey of current practice conducted for the project indicated that no quantitative evaluation of this concept has been conducted.

We compared the number of DVC/year before and after mowing was reduced at six locations in Maryland and four locations in New York to determine if there was a statistically significant difference in the DVC rate between the two time periods. Consistent with standard safety data analysis practices, we compared three years of before data to three years of after data. We followed the comparison of before/after data with an examination of the predictive relationship of mowing regime on DVC rate. Five of the study areas reported more DVC/year after mowing was reduced, four study areas reported more DVC/year before mowing was reduced, and one study area experienced essentially no change. The results from three of the New York study areas were marginally significant ($p = 0.10$), but the direction of the changes was inconsistent. None of the Maryland study area changes were significant. The R^2 values between DVC and mowing were significant (p value < 0.05) for only one of the ten study areas tested.

Because of the small samples sizes used, the results of this analysis should be interpreted with care. However, the results do not indicate that DVC rates are related to mowing regime.

TASK 5 FINAL REPORT: DVC-REDUCED MOWING IMPACTS

1.0 INTRODUCTION

This project was funded by the Deer-Vehicle Crash Information and Research (DVCIR) Center and the Federal Highway Administration (FHWA) Surface Transportation and Environment Planning (STEP) program. The DVCIR Center is a multi-state pooled fund project which also includes the FHWA as the lead agency, and is funded by nine State Departments of Transportation (DOT's) consisting of Connecticut, Iowa, Maryland, Minnesota, New Hampshire, New York, Ohio, Texas, and Wisconsin. The primary goal of this project was to learn more about potential safety, ecological, and economic impacts of reduced roadside mowing, to identify and describe roadside vegetation management policies currently in place throughout the United States, and to quantify DVC impacts of reduced roadside mowing.

Primary Project Goals

- Learn more about potential safety, ecological, and economic impacts of reduced roadside mowing
- Identify and describe roadside vegetation management policies currently in place throughout the United States
- Quantify DVC impacts of reduced roadside mowing

To meet this goal, the main objectives of the investigation were to:

- Review and summarize the research focused on the ecological, economic, and safety impacts of reduced roadside mowing policies.
- Define and document the "typical" roadside vegetation management policies currently applied in the United States.
- Investigate and quantify the potential animal-vehicle collision (AVC) and/or deer-vehicle collision (DVC) safety-related impacts of reduced roadside mowing policies in comparison to "typical" or more frequent mowing practices.
- Produce a report that describes the "best practices" in the area of roadside vegetation management and decision-making guidelines.

To meet the main objectives of this project, the investigation was broken into three primary tasks:

- **Literature review:** Current literature was reviewed and summarized to describe the potential safety, economic, and ecological impacts of roadside vegetation management policies and practices, including reduced roadside mowing.
- **Current and "Best" Practice Survey:** A survey of 24 different DOTs was conducted to identify and describe roadside vegetation management policies currently in place throughout the United States, and to determine if the policies used by the pooled fund member states were a typical representation of those used throughout the country. For states that had a reduced mowing program, the differences between their “typical" and "reduced" roadside mowing

practices were identified. Any discussions of DVC or AVC impacts considered within these policies were also noted.

- **Quantify DVC Impacts of Reduced Roadside Mowing:** The potential safety impacts of reduced roadside mowing were quantified using existing data sets from two states, Maryland and New York. An experimental design report describes the methodology developed to evaluate the differences in DVC rates between "standard" mow and reduced mow regimes, and the results.

Summarized In This Report

- **Task 2:** Literature Review of safety, economic and ecological impacts of roadside vegetation management.
- **Task 3:** Survey of current roadside vegetation management practices
- **Task 4:** Efforts to quantify DVC impacts of reduced roadside mowing

Results of the literature review (Task 2), a survey of current roadside vegetation management practices (Task 3) and efforts to quantify DVC impacts of reduced roadside mowing (Task 4) are summarized in this report. The complete results for the literature review are in Appendix A, and the complete survey report is supplied in Appendix B.

2.0 SUMMARY OF SAFETY, ECONOMIC AND ECOLOGICAL IMPACTS

2.1 SAFETY IMPACTS

Over 29,000 human injuries and over 200 human fatalities caused by DVCs are estimated to occur annually in the United States (Conover et al. 1995). Of primary interest to this project is how roadside vegetation management (reduced roadside mowing, planting, cutting woody vegetation) affects DVCs and thus highway safety. Two aspects of roadside vegetation management hypothesized to increase DVCs are:

- The attraction of deer to the highway to feed on roadside vegetation, and
- The reduction of roadway visibility caused by higher and/or denser vegetation, making it more difficult for motorists to detect and avoid deer on the roadway.

2.1.1 Attraction of deer to roadside vegetation

Briefly

Evidence of deer being attracted to ROW vegetation was much more pronounced in forested landscapes as compared to agricultural landscapes.

There are a number of factors that govern the variation in attractiveness of roadside vegetation to deer. They include the palatability of the roadside vegetation, the timing, abundance and nutritional quality of alternative natural foods available to the deer, landscape vegetation characteristics, and seasonal differences in energy requirements for deer. For example, along Interstate 80 (Puglisi et al. 1974), and Interstate 84 (Feldhamer et al. 1986) in Pennsylvania, evidence of deer being attracted to right of way (ROW) vegetation was much more pronounced in forested landscapes as compared to agricultural landscapes. This deer movement pattern makes sense nutritionally, because there is less incentive for deer to be attracted to roadside vegetation in agricultural landscapes where high quality foods are typically more ubiquitous and abundant than in landscapes dominated by forest. Likewise, roadside vegetation would be expected to be less of an attractant for deer living in forested landscapes at times when high energy foods such as acorns or beechnuts are abundant, as compared to times when these high energy foods are lacking.

Management decisions on when to cut woody vegetation, when to mow grass and herbaceous growth, or which plants to establish for roadside vegetation all have potential implications for highway safety as these actions affect the quality of forage for deer available on the roadside. Mechanical trimming of woody vegetation during mid-summer has been shown to improve digestibility in subsequent regrowth, making it more attractive to deer (or any other animals that feed on browse) for up to three years (Rea 2003). Managers can, however, impact the quantity and nutritional quality of the woody regrowth by changing the timing of cutting (Jaren et al. 1991, Rea and Gillingham 2001, Rea 2003, Rea et al. 2007). Rea (2003) recommended brush cutting be done early in the growing season, and to avoid brush cutting in the more traditional mid-summer period, to reduce attractiveness to browsing species such as deer.

> **Briefly**
>
> Mechanical trimming of woody vegetation during mid-summer has been shown to improve digestibility in subsequent regrowth, making it more attractive to deer (or any other animals that feed on browse) for up to three years.

Prevention of soil erosion, establishment of a clear line of sight along highways, and control of invasive species are important objectives of DOTs when selecting plants for revegetating roadsides after construction projects are completed. Another important consideration for highway safety, especially where deer densities are high, is to select plants that are not preferred by deer. This can present a challenge as the candidate plants species available may not meet all of the desired objectives, resulting in unavoidable compromises. For example, crownvetch (Coronilla varia) is a cool season, hardy, perennial legume particularly well adapted to road bank stabilization, often planted on steep slopes along interstate highway borders in the northeastern United States. However, two studies along interstate highways, one in West Virginia (Michael 1980) and another in Pennsylvania (Feldhamer et al. 1986) reported that white-tailed deer were attracted to crownvetch plantings. Food preferences of deer can vary regionally and seasonally based on availability of other foods. Deer will almost always be attracted to roadsides in spring if that is the first location to “green-up”.

> **Briefly**
>
> An important consideration for highway safety is to select plants that are not preferred by deer.

Knowledge of the plant species that are preferred or avoided by deer can be helpful in the selection for seeding roadsides. Environmental characteristics specific to the road site such as soil quality, precipitation, seasonal temperature fluctuations, and amount of sunlight are all likely to be important in selecting candidate plants for roadside vegetation establishment. The Minnesota Department of Transportation has developed a “Plant Selector” program (http://dotapp7.dot.state.mn.us/plant/) to assist in the selection of potential roadside plants to match the characteristics of the roadside of interest. The user of this program selects the planting site characteristics (>25 to pick from), the plant characteristics (20 selections), type of plant (tree, shrub, grass, sedge, fern, etc.) and the program makes a selection of plants that meet the criteria entered by the user. Agricultural Extension services of major universities in the geographical area of interest can also often be another good source of this type of information.

2.1.2 Reduction of Roadway Visibility

Roadway visibility changes both temporally and spatially. Obstruction of visibility is greater for deciduous trees and shrubs when their leaves are present during the growing season. The timing of mowing cycles and the stage of growth of grassy/herbaceous areas affect driver visibility and thus may also affect DVC probability. We reviewed five DVC quantitative models that evaluated at least one variable associated with visibility of the roadway as a function of the surrounding vegetation (Bashore et al. 1985, Biggs et al. 2004, Finder et al 1999, Malo et al. 2004, Romin and Bissonette 1996). Only one (Bashore 1985) found roadway visibility to be a significant factor in predicting DVCs. However, visibility in these models was not defined using the same approach applied by road safety engineers, and it is unclear if the variables measured have any bearing on a driver's ability to perceive deer on the roadside.

Our literature review uncovered only three studies that explicitly examined any type of animal-vehicle collisions to roadside/railroad visibility or vegetation management: one reported on moose-vehicle collisions in Sweden (Lavsund and Sandegren 1991) and the other two reported on moose-train collisions in Norway (Jaren et al. 1991, Andreassen et al. 2005). All three studies suffered from either experimental design flaws or non-significant results that invalidate their study conclusions for our purposes.

In the moose-vehicle study in Sweden (Lavsund and Sandegren 1991), the treatment involved clearing bushes and removing tree branches below three meters' height in a 20-meter strip along the road. No clearing occurred on the control areas. Reportedly the experiment showed an accident reduction of nearly 20%; however, the significance is questionable as the author did not provide statistical documentation and admittedly stated that this 20% reduction was "very close to a result which might have been expected just due to chance."

Jaren et al (1991) reported on an experiment in Norway where vegetation was removed in a 20-30 meter-wide sector on each side of the railway line, which reportedly caused a 56% (+/- 16%) reduction in moose-train kills (collisions). However, due to several study design flaws, these results are also questionable. First, the treatment and control areas were not comparable. The treated area consisted of two sections that were determined to have "high accident risk" based on a previous four-year study, and the remaining areas (low risk areas) were designated as control areas. The second possible problem in experimental design was that treated and control areas were adjacent. The treatment (removal of vegetation) may have led to moose moving to the control areas, resulting in increased mortality on the control areas. These study design problems are stated in the publication.

Andreassen et al. (2005) reported on an experiment in Norway where a 46% reduction in train-moose collisions occurred in the treated areas; however, there were three treatments (scent-marking, forest-clearing, and supplemental feeding) and due to temporal and spatial differences in the application of the treatments, the effects of forest-clearing alone could not be determined.

We were unable to locate any scientific literature that examined the rate of frequency of DVCs in North America to any aspect of roadside vegetation management policies, including reduced roadside mowing.

2.2 ECONOMIC IMPACTS

The economic impacts of reduced roadside mowing include the anticipated savings from decreased labor and material costs for maintenance associated with a reduction in mowing activities, and the costs associated with any mowing-related rise or decline in the number of DVCs. Dishneau (2009) indicated that Virginia anticipated a 50% reduction in roadside mowing in 2009 that was estimated to save approximately $20 million. From a survey of DOTs conducted as part of Task 3 of this project we determined the following:

- Georgia estimated an annual savings of $3,261,441 by reducing the number of annual mowing from 3 to 2 on just their Interstate system in 2009.
- Maine estimated an annual savings of about $850,000 by a reduction in areas mowed in rural areas which went into effect after 2006.
- Maryland estimated an annual savings of about $3-5 million by reducing the number of full annual cuttings from 4-6 down to 2 in 2009.
- Pennsylvania reported an estimated savings of about $2 million in 2008, compared to 2007, when they reduced from 3-4 full cuts to a single full cut annually.
- Texas reported an estimated savings of about $20 million in 2010 by reducing the number of mowing cycles from 3-4 down to 2-3.
- Wisconsin reported an estimated annual savings of about $2.5 million in 2009 after reducing the number of annual mowings from 2-3 down to just 1.

Briefly

The economic impacts of reduced roadside mowing include:

- Anticipated savings from decreased labor and material costs for maintenance associated with a reduction in mowing activities
- Costs associated with any mowing-related rise or decline in the number of DVCs

With regard to economic impacts of DVCs, we were not able to locate any literature that documented a change in DVCs related to any existing reduced roadside mowing policies and no such data was available from any of the 24 state DOTs that we surveyed in conjunction with this project.

Huijser et al. 2009 provided the most useful and well documented cost estimate for DVCs that was located in the literature review associated with Task 2 of this project. Average vehicle repair costs were based on information obtained from State Farm Insurance for 178,500 recent DVC claims. The calculations for human fatality costs were based on results of studies of the incidence of fatalities in DVCs, and the basis for the monetary value for a deer was based on hunting values.

Knowledge of the calculations, assumptions, and supporting evidence for DVC cost estimates is important for DOTs in mitigation programs. A summary of estimated DVC costs, assumptions, calculations, and supporting evidence presented in Huijser et al. 2009 is supplied in Table 1. All estimates are in 2007 US$ using the U.S. Consumer Price Index (U.S. Department of Labor 2008) and are based on Huijser's review of the literature.

Though a reduced roadside mowing policy is anticipated to save money from decreased labor and material costs, as can be seen in Table 1, DVC-related costs are substantial ($6,617 per DVC), and even a small change in the rate of DVCs could have a significant effect on the overall costs related to a change in mowing practices.

Table 1. Assumptions, calculations, and supporting evidence for estimated costs (in 2007 US$) for the average deer-vehicle collision (From Huijser et al. 2009).

Description	Cost (US $)	Assumptions and Calculations	Supporting Evidence and Comments
Vehicle repair costs per collision	$2,622	92% of DVCs result in vehicle damage. $2,850 = average repair bill Calculation: $2,850 x .92 = $2,622	90.2% in NS: Tardif & Associates 2003 94% in UT: Romin and Bissonette 1996 $2,850/claim : from State Farm Insurance based on 178,500 DVC claims.
Human injuries per collision	$2,702	5% of DVCs result in human injury 3 types of human injuries occur in the following proportions and estimated costs: 51.4% are classified as “possible” ($24,418 each), 38.4% as “evident” ($46,266 each) and 10.3% as severe ($231,332 each). Calculation: ($24,418 x .514 x .05) + ($46,266 x .384 x .05) + ($231,332 x .103 x .05) = $2,702	2.8% in MI: SEMCOG 2007 3.8% in US Midwest: Knapp et al. 2004 4.0% in US: Conover et al 1995 7.7% in OH: Schwabe et al. 2002 9.7% in NS: Tardif & Associates 2003 Huijser et al. 2007 U.S. Deptment of Transportation 1994 $2,702 estimate includes lost earnings, lost household production, medical costs, emergency services, travel delay, vocational rehabilitation, workplace costs, administrative, legal, and pain and lost quality of life.
Human fatalities per collision	$1,002	Each DVC results in an average of 0.0003 human fatalities. Each human fatality costs $3,341,468. Calculation: $3,341,468 x 0.0003 = $1,002	0.00009 in OH: Schwabe et al. 2002 0.00020 in MI: SEMCOG 2007 0.00029 in NA: Schwabe et al. 2002 0.0003 in Midwest: Knapp et al 2004 0.0005 in NS: Tardif & Associates 2003 U.S. Dept. of Transportation 1994 Huijser et al. 2007
Towing, accident attendance, and investigation	$125	Only 25% of DVCs require these services $500 = average cost for these services. Calculation: $500 x .25 = $125.	Clayton Resources Ltd. & Glen Smith Wildlife Consultants 1989
Hunting value for deer per collision	$116	$441 = average value/deer (2007 US$) 0.61 = hunter success rate for deer $723= value for successful hunting season Calculation: $441/.61 = $723 0.16 = proportion of pre-hunting deer population taken by hunters in US Calculation: $723 x .16 = $116	U.S. Fish and Wildlife Service 2003 U.S. Fish and Wildlife Service 1998 Crete and Daigle 1999
Carcass removal and disposal per collision	$50	Each DVC would require removal and disposal at $50 each.	Can $100: Sielecki 2004 $30.50: for PA contractors or $52.46 for PennDOT: Personal communication Jon Fleming, PenDOT
Total	$6,617		

2.3 ECOLOGICAL IMPACTS

The stated goal of the discussion of ecological impacts was to focus on deer and how they might be affected by roadside vegetation management in general, and a reduced mowing policy in particular. After expending considerable effort reviewing the literature, it became obvious that published studies on ecological impacts of roadside vegetation management on deer were unexpectedly scarce. Considering the enormous amount of research that has been conducted on deer, their economic importance, and their prominent role in highway safety, it was especially surprising that ecological research studies of roadside vegetation management impacts on ring-necked pheasants, waterfowl, songbirds, insects and spiders appeared to be more common. The results of these studies demonstrate that roadside vegetation management decisions do have significant ecological impacts on species with relatively small body sizes. These species have relatively small home ranges that may be largely or fully encompassed by the managed areas adjacent to a roadway, and the effect of vegetation management on them therefore should not be surprising. Deer, with a relatively larger home range that would be minimally influence by affected vegetation management practices would logically be expected to experience a smaller affect. Never-the-less, we have incorporated a few paragraphs into this report describing results of ecological impact studies of roadside vegetation management on a variety of species other than deer.

Literature Review Findings

- Studies on ecological impacts of roadside vegetation management on deer were unexpectedly scarce.
- Ecological research studies of roadside vegetation management impacts on ring-necked pheasants, waterfowl, songbirds, insects and spiders appeared to be more common

2.3.1 Deer/Ungulates

We were unable to locate any scientific literature from any studies of the ecological impacts on deer specifically from a reduced roadside mowing policy. We did, however, locate a very limited number of studies that discussed ecological impacts of other aspects of roadside vegetation management that are discussed below.

One ecological impact of roadside vegetation on deer is that it is often used as a source of food. This may be a benefit to deer nutritionally; however, crossing roads to get to the vegetation constitutes a risk of collision with automobiles which is fatal to deer greater than 90% of the time (Allen and McCullough 1976). The selection of plants used to revegetate roadsides, based on their nutritional value and palatability to deer, and the distribution and availability of alternative food sources within the deer's home range are all likely to impact the degree to which deer will be attracted to the roadway. For example, crownvetch, a plant often used for road bank stabilization in the northeastern United States, has been documented to attract deer in West Virginia (Michael 1980) and in Pennsylvania (Feldhamer et al. 1986). Also, where interstate highways intersect major forested landscapes deer have been documented to be particularly attracted to roadside vegetation (Puglisi et al. 1974, Feldhamer et al. 1986) especially during times of the year when high-energy mast crops are not available.

Cutting woody vegetation may also result in regrowth that attracts deer to the ROW. Deer prefer to browse fresh new woody growth, but the seasonal timing of cutting has been found to impact the attractiveness of new growth to herbivores such as deer. Studies in British Columbia found that the timing of brush-cutting influences morphology, phenology, and digestibility of plants for up to three years (Rea and Gillingham 2001, , Rea 2003, Rea et al. 2007). Cutting in mid-summer can result in more digestible regrowth in the following years and may attract deer and other herbivores to the cutting site. Rea (2003) recommended cutting brush early in the growing season to reduce its attractiveness to herbivores. In some cases the timing of pruning may be restricted legislatively. In Texas, for example, due to the Migratory Bird Treaty Act, pruning must occur after October (Personal communication Dennis Markward, TxDOT).

2.3.2 Other Wildlife

The location, timing, frequency, and height of mowing are all important ecologically as they control the wildlife habitat that develops on the ROW (Forman et al. 2003), which in turn determines the distribution, abundance, and composition of wildlife communities that may use the ROW. For example, if habitat is created that supports large populations of small mammals (mice, voles, moles, shrews, etc.) and/or ground nesting songbirds, then the ROW is more likely to attract raptors (red-tailed hawk, red-shouldered hawk, American kestrel, etc.) and medium-sized predators such as red or gray foxes, opossums, or skunks. Development of plant communities with abundant blossoms within the ROW has been documented to increase populations of bees (Hopwood 2008), butterflies (Ries et al. 2001), and other pollinating insects (Noordijk et al. 2009), which stimulates pollination in the area and, of course, attracts additional predators of the pollinating insects.

Mowing Variables That Impact Habitat

- Location
- Timing
- Frequency
- Height of mowing

Results of Mowing Impact on Habitat

Moving variables control the wildlife habitat that develops on the ROW. This determines the distribution, abundance, and composition of wildlife communities that may use the ROW.

Mowing during late spring and early summer has been documented to cause mortality of young ground-nesting birds and mammals, but this impact can be reduced by delaying mowing until after they have left their nests (Wilkins and Schmidly 1981). For example, Oetting and Cassel (1971) recommended no mowing before July 20 to enhance waterfowl nesting success in duck-producing regions of North Dakota and three ring-necked pheasant research projects in Illinois recommended that roadside mowing be delayed until August 1 to improve nesting success (Joselyn et al. 1968, Joselyn and Tate 1972, Warner et al. 1992).

Mowing regimes that create a more variegated complex pattern and composition of roadside vegetation tend to support greater species richness, while widespread frequent mowing favors the spread of grasses at the expense of most native plants (Foreman et al. 2003). Recommendations for rotational roadside mowing regimes or maintenance of refuges (areas not mowed) were specifically mentioned in ecological research publications to improve the abundance of waterfowl (Voorhees and Cassel 1980), pollinating insects (Noordijk 2009) and spiders (Cattin et al. 2003).

A variety of research studies summarized in Table 2 have shown that modifications of roadside vegetation management resulted in increases of targeted animal populations. Adjustments to roadside vegetation management included plantings and changes in mowing frequency and timing, while target species included waterfowl, ring-necked pheasants, bees, native butterflies, as well as birds and mammals in general.

Table 2. Ecological research studies that have documented modifications of roadside vegetation management that resulted in increases of targeted animal populations.

Ecological Study	Wildlife Species/ Class	State	Treatment/Control	Population Response
Joselyn et al. 1968	Ring-necked Pheasant	Illinois	Treatment: Roadsides seeded to grass-legume mixture and only mowed once per year, delayed until after Aug. 1. Control: Roadsides unseeded (old bluegrass sods and annual weeds), and mowed 3 or more times a year, at least once prior to August 1.	Increased: 3.0 nests/ acre on treatment and 1.5 nests/acre on control area
Hopwood 2008	Bees	Kansas	Treatment: Roadsides restored to native prairie vegetation. Control: Roadsides dominated by weedy, non-native vegetation.	Increased: Restored native prairie supported significantly greater bee abundance and higher species richness
Oetting and Cassel 1971	Waterfowl	North Dakota	Treatment: No mowing in fall to increase cover in the spring. Control: Mowed in fall resulting in less cover in the spring	Increased: Ducks chose unmowed (treated) areas significantly more often and had higher nesting success
Ries et al. 2001	Butterflies	Iowa	Treatment: Roadsides restored to native prairie vegetation with restricted use of mowing and herbicides. Control: Roadsides dominated by weeds (non-native legumes) or non-native grasses with mowing and use of herbicides—traditional roadside mgmt for exotic grassy monoculture.	Increased: 2-fold increase in species richness and 5-fold increase in abundance for habitat-sensitive butterflies.
Roach and Kirkpatrick 1985	Birds & Mammals	Indiana	Treatment: Roadside shrub plantings in plots 328' long. Control: Grassy roadsides	Increased: Numbers of rabbits & birds in shrub test plots were significantly greater.

3.0 SUMMARY OF CURRENT PRACTICES

A survey of 24 state DOT's was conducted to document the "typical" roadside vegetation management policies and "best" management practices currently applied in the United States, and to determine if policies used by pooled fund member states were typical of those used throughout the country. Email-questionnaires and follow-up phone interviews were conducted to gather information on roadside vegetation management policies currently in place in each of the nine pooled fund member states and a sample of 15 non-member states throughout the country (Figure 1). The results of the survey are summarized below and the full report from this task is available in Appendix B.

3.1 WHERE, WHEN, AND WHY ROADSIDE MOWING WAS REDUCED

A reduction in roadside vegetation mowing has occurred throughout a majority of the United States in recent years based on results from this survey. Twenty-one of 24 states (88%) that responded to the survey reported a reduction in their mowing programs (Table 3). For those 21 states that reduced mowing, 17 did so statewide while 4 reduced mowing in only some parts of their state.

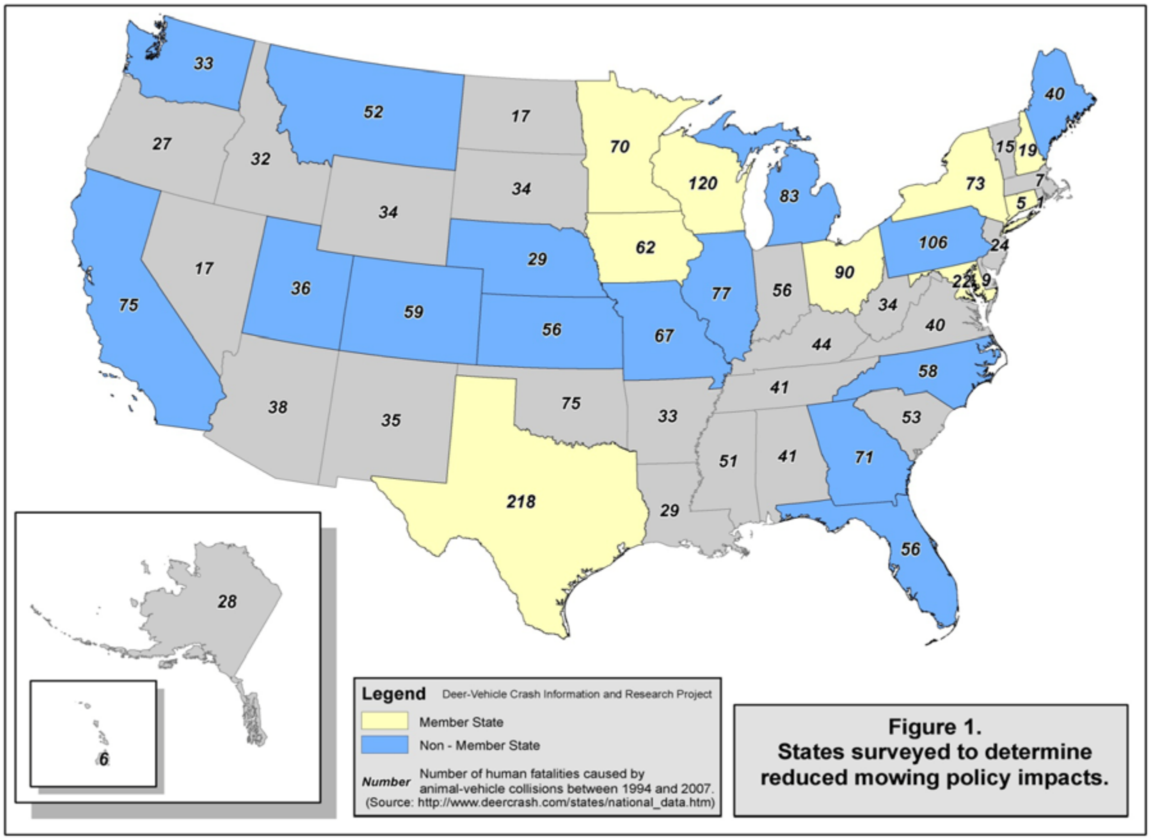

Figure 1. States surveyed to determine reduced mowing policy impacts.

The timing of when roadside mowing programs were reduced varied from 1968 to 2010; however, nearly two-thirds (13/21=62%) of the states that had reduced mowing programs made their reductions in the past three years (2008-2010); 81% (17/21) in the past 7 years (2004-2010).

Economic concern was the overwhelming reason provided why roadside mowing programs have been reduced in surveyed states while ecological and safety concerns were listed secondarily (Table 3). All 21 (100%) of the responding states indicated economic concern was a factor in the decision to reduce mowing, 13 states (62%) also listed ecological concerns, and 4 states (20%) listed safety as a concern. Ecological concerns included impacts on survival of ground nesting birds, establishment of native plants, and weed control. In Iowa and Michigan reduced roadside mowing programs were mandated by legislation to improve nesting success for ring-necked pheasants and other ground nesting birds. In Maine the reduction was brought on by a

Reasons for Reduced Roadside Mowing

Primary: Economic

Secondary: Ecological and safety concerns

Ecological Concerns for Reduced Mowing

- Impact on ground-nesting birds
- Establishment of native plants
- Weed control
- Reduce reliance on fossil fuels

governor's executive order to reduce reliance on fossil fuels. Safety of a reduced mowing program was listed in four states in reference to an anticipated reduction of exposure (danger) of DOT employees to the traffic as a result of reduced time mowing along roadways (positive concern), and/or a concern that reduced mowing would adequately maintain safety sight distance and clear zones (negative concern).

Table 3: Where, When, and Why Roadside Mowing Was Reduced in 24 Surveyed States

STATE	REDUCED MOWING POLICY			CONCERNS AND LEGISLATION THAT LED TO REDUCED MOWING			
	Yes/No	Year Implemented	All/Part of State	Safety	Economic	Ecological	Legislation
California	No		None				
Colorado	Yes	2000	Part		X	X	
Connecticut[1]	Yes	2009	All		X		
Florida	No		None				
Georgia	Yes	2009	Part		X		
Illinois	Yes	2005	All		X		
Iowa	Yes	1970's & 2010	All		X	X	X
Kansas	Yes	2009	All		X	X	
Maine	Yes	2006	All		X	X	
Maryland	Yes	2009	All		X		
Michigan	Yes	2008	All		X		X
Minnesota	Yes	1989	All		X	X	
Missouri	Yes	1980's & 2005-2009	Part		X	X	
Montana	Yes	2006	All	X	X	X	
Nebraska	Yes	1968	All		X	X	
New Hampshire	Yes	2004	Part		X		
New York	Yes	2008	All	X	X	X	
North Carolina	No		None				
Ohio	Yes	2010	All	X	X	X	
Pennsylvania	Yes	2008	All		X	X	
Texas	Yes	2010	All		X		
Utah	Yes	2008	All		X	X	
Washington	Yes	2001	All	X	X	X	
Wisconsin	Yes	2009	All		X		

[1]Pooled fund member states are underlined and highlighted in yellow.

The nine pooled fund member states appear to be comparable to the rest of the country (or at least the 15 surveyed non-fund states) with regard to reduced mowing policies. A vast majority of both member (9/9=100%) and non-member (12/15=80%) states reported having reduced mowing policies which were largely implemented in the past 7 years. All member (9/9=100%) and non-member (15/15=100%) states indicated economic concerns led to reduced mowing policies; roughly half of member (4/9=44%) and non-member (8/15=53%) states expressed ecological concerns, and a minority of both member (2/9=22%) and non-member (2/15=13%) states indicated that safety concerns led to reduced mowing policies. Of the two surveyed states where legislation created reductions in roadside mowing programs, one (Iowa) was a member and one (Michigan) was a non-member.

3.2 Comparison of "Typical" and "Reduced" Mowing Policies

A comparison of “reduced” and “typical” mowing policies for each of the 21 responding states that reported a reduced mowing policy involved a combination of changes in the number of mowing cycles per year, seasonal timing of mowing, areas mowed, and/or mowing height (Table 4). A reduction in the number of mowing cycles and/or areas mowed was reported for all 21 of the responding states with “reduced” mowing policies. However, a reduction in mowing height and/or changes in the timing of mowing was less common, involving only 8 of those 21 states. Washington reported that a higher mowing height was advantageous to plant stability and sustainability.

Table 4. Comparison of "Typical" and "Reduced" Mowing Policies for 21 States with Reduced Mowing Policies.

State	#of Mowing Cycles		Timing of Mowing		Areas Mowed		Mowing Height (In)	
	Typical	Reduced	Typical	Reduced	Typical	Reduced	Typical	Reduced
CO	2	1	Spring & Fall	Late Spring or Fall	15 ft from pavement edge	15 ft from pavement edge	6-8	6-8
CT[1]	2-3	2	No Dates Required	No Dates Required	All ramp & bowl areas	Ramp & bowl areas to 16 ft from pavement edge	3	3
GA	3[2]	2[2]	May 1-Sep 15	May 1-Sep 15	Same as reduced	Same as typical	6	6
IL	3+	2	1st by July 1 2nd as needed 3rd as needed	1st by Memorial Day 2nd after Labor day	Same as reduced	Same as typical	6	6
IA	3[3]	<3[3]	Spring through Fall	After July 15th	ROW to ROW	Only areas needing weed or brush control or sight distance	3-4	6
KS	?	?	April 15-July 15	April 15-Oct 1	Shoulder and Sight Triangles	Shoulder and Sight Triangles	6	6
ME	1[4]	0-1[4]	Mid May-Mid Nov	Mid May-Mid Nov	Same as reduced	Same as typical	4	4
MD	4-6[5]	2[5]	May through Oct	May through Oct	Mowable medians & roadsides-full cuts	Mowable medians & roadsides (only 1 pass for 3-4 cuts + 2 full cuts)	3.5-4.5	3.5-4.5
MI	3-5	1	May, July, Sep	June	12 ft adjacent to shoulder and wider at clear vision areas	12 ft adjacent to shoulder and wider at clear vision areas	5	5
MN	2+	1-2	May to Oct	After Aug 1 except for top cut & weeds	Entire ROW each year	Entire ROW once every 5 years	4-6	4-6
MO	[6]	[6]	[6]	[6]	Greater acreage	Reduced acreage	[6]	[6]
MT	1-3	1-3	May and June	July[7]	Beyond 15 ft from edge of	Concentrated mostly within 15'	<6	6-8

State	#of Mowing Cycles		Timing of Mowing		Areas Mowed		Mowing Height (In)	
	Typical	Reduced	Typical	Reduced	Typical	Reduced	Typical	Reduced
					pavement	from edge of pavement		
NE	2-3	2-3	May-Oct	May-Oct	ROW to ROW	15' from edge of pavement	5	5
NH	1[8]	0[8]	May 1-Oct 1	May 1-Oct 1	To tree line 1 year, to ditch line 2nd yr	Mostly just intersections	4-6	4-6
NY	2-3	2-3	May-Dec	May-Dec	ROW to ROW	15 ft from pavement for first 2 mowings, 3 pass on final mowing to control woody veg.	4	4
OH	4	3	May-Oct	May-Oct	Recovery zone (30 ft from white line) 3 times/yr, full cut for final mowing	Recovery zone (30 ft from white line) 2 times/yr, full cut for final mowing	6-8	6-8
PA	3-4	3-4	May 15-Sep 15	May 15-Sep 15	Full width to slope or ROW 3-4/yr	Full width to slope or ROW 1/yr, 2-3 limited mowings (10 ft wide on right side and 5 ft wide everywhere else).	3-5	4-8
TX	3-4	2-3	All 12 months	All 12 months	Same as reduced	Same as typical	5-7	5-7
UT	1	1	July-Sep	July-Sep	ROW to ROW 1/yr	1 pass (6-8 ft) 1/yr, ROW to ROW 1/3-5 yr	6	6
WA	Up to 4	<4	April-Sep	April-Sep	ROW to ROW	1 pass	2-6	6-8
WI	2-3	1	June-July 4	June-July 4	1 pass	1 pass	> 6	> 6

[1]Pooled fund member states are underlined and highlighted in yellow.
[2]Reduction in number of mowing cycles in Georgia pertained only to interstate highways.
[3]Reduction in number of mowing cycles in Iowa went from 3 (typical) to "only as needed for safety or operational purposes".
[4]Reduction in number of mowing cycles applies only to rural roads in Maine.
[5]"Typical" number of mowing cycles in MD was 4-6 full cutbacks, "reduced" policy involved only 2 full cutbacks and 3-4 one pass cuts.

[6]Was unable to get specific data for Missouri.
[7]Reduced mowing policy in MT delays mowing until after July 1 to let desirable species mature (reproduce).
[8]In NH all roads typically mowed once but, depending on budgets, recently some years mowing is restricted to intersections & sightline issue areas.

With regard to "typical" and "reduced" mowing policies, Pooled Fund member states appear to be comparable to the rest of the country. All of the Pooled Fund states (9/9=100%) and all of the non-fund states with reduced mowing policies (12/12=100%) reduced either the number of mowing cycles and/or the areas mowed. Only half or less of the pooled fund states (2/9=22%) and non-fund states with reduced mowing policies (6/12=50%) reduced mowing height and/or timing of mowings.

3.3 How and Why Timing, Frequency and Height of Mowing Differ

Mowing regimes are typically not the same throughout all areas within most states for a variety of reasons (Table 5). Mowing requirements are impacted by differences in temperature and rainfall due to changes in latitude, topography, and/or elevation which in turn impacts grass species composition, length and timing of growing seasons, and growth patterns. Different classifications of roads, the location within the ROW and the purpose of mowing (or not mowing) also impact mowing regimes within a state. Interstate (multi-lane) highways tend to have more mowing cycles than secondary roads. For safety reasons, locations nearest the roadway that may impact sight distance tend to be mowed more frequently than areas beyond the recovery zone. As a rule, there tend to be more mowing cycles, lower mowing heights, and more of the ROW areas mowed in urban areas and other high human use areas, such as rest areas and visitor centers, than in rural areas. Other factors that contribute to a variety of mowing regimes being used within a state are the concern of mortality of ground nesting birds during the nesting season, control of weeds (mowing prior to seed production of weed species), establishment and maintenance of more desirable native vegetation, drought conditions, and fire safety.

Factors that Affect Mowing Regimes

- Temperature and rainfall (which impact grass species composition, length and timing of growing seasons, and growth patterns)
- Classifications of roads
- Location within right of way
- Ecological factors

3.4 Influence of DVC on Roadside Vegetation Policies

Nine states commented on DVC or AVC considerations for policies dealing with either mowing or clearing of woody vegetation from highways. Ohio reported a desire to keep the recovery areas mowed so that motorists can see deer soon enough to react. Washington stated that areas with known DVC are mowed out wider, and New York stated that there was no systematic evidence to date of a relationship of mowing to DVC/AVC. Six states (CT, ME, MT, NH, PA, and WA) indicated that they had policies to clear woody vegetation from highways in an effort to reduce DVC or AVC.

Five states (GE, MT, NY, TX, and WA) commented on DVC considerations for planting policies. Georgia discouraged the planting of certain oaks that have acorns that are especially attractive to deer. Montana plants lower growing grasses that are undesirable forage to prevent attracting deer and to improve sight distance. New York attempts to plant only vegetation that does not attract deer and no longer plants clover for that reason, and Washington also avoids planting clover as a ground cover because of its grazing attraction. Texas indicated it is looking for alternative cool season temporary covers to replace wheat and oats.

Fifteen (63%) of the 24 surveyed states indicated that neither a perceived or demonstrated reduction in DVC played a role in current roadside vegetation management policies while 9 states reported a perceived reduction. We found no evidence from the survey that a demonstrated (quantified) reduction of DVC rates had been documented in any state due to changes in roadside vegetation management policies.

Table 5. Number of Mowing Cycles, Mowing Dates, and Mowing Heights for 24 Surveyed States.

State	Mowing Same Statewide?[1]			Number of Mowings	Mowing Dates	Mowing Height	Comments
	Number	Dates	Height				
CA	No	No	No	1-3	Mar-Sep	6-12	#: variable based on eco province, vegetation type, location, funding, equipment, history, etc. Dates: Varies with Eco Provinces and rainfall.
CO	No	No	Yes	Variable	May-Oct	6-8	#: variable based on wide variety of terrain and climate. Dates: Vary with elevations which range 3,000-14,000'.
CT[2]	No	No	Yes	2-3 secondary, variable on multi-lane rds.	Variable	3	#: 2-3 on secondary roads but variable on multi-lane roads- whenever grass reaches 8". Dates: Whenever grass reaches 8"
FL	No	No	Yes	Variable	Variable	5-18	#: determined by when grass reaches mowing height.
GA	No	No	Yes	3 on Interstate, 2 on other rds.	May-Sep	6	Dates: First mowing cycle typically begins between May 1-15. Final mowing cycle begins Sep 1-15.
IL	No	Yes	Yes	Variable	Late Spring-Late Fall	6	#: of mowing variable based on local conditions. Date: Growing season longer in southern IL.
IA	No	Yes	Yes	Variable	After July 15th	6	#: based on when grass gets to mowing height and mowing purpose. Dates: Most mowing delayed until after July 15 to improve nesting success of ring-necked pheasants and other ground nesting birds.

State	Mowing Same Statewide?[1]			Number of Mowings	Mowing Dates	Mowing Height	Comments
	Number	Dates	Height				
KS	No	Yes	Yes	1	April 15-Winter	6-8	#: Entire ROW mowed once every 4 years. Shoulder and sight distance mowing as needed. Dates: Shoulder mowing April 15 to Oct 1. Mow out of ROW after Oct 1. Height: 6"for shoulder and sight distance, 8" mow out of ROW.
ME	No	No	Yes	2-3 in S Maine, 1 in N Maine	May-Nov	2.5-4	#: Mowing more cycles in southern Maine because growing season is longer and rate of growth is higher. Height: 4" for Interstate inslopes and backslopes, 2.5" for urban interchanges.
MD	Yes	No	Yes	2	Variable	2.5-4.5	#: 2 full cutbacks plus 3-4 one-pass cuts. Dates: Vary with elevation-longer growing season near coast. Height: Tractor mowing is 3.5-4.5", hand mowing is 2.5-3.5".
MI	Yes	Yes	Yes	1	June 1-July 4	5	
MN	No	Yes	Yes	Variable	May-Oct	4-6	#: Based on vegetation growth rate, rural or urban, and location in ROW.
MO	No	No	No	Variable	Pre-Memorial Day-Post Labor Day	4-6	#: Urban areas mowed more frequently than rural areas.
MT	No	Yes	Yes	Variable	July-Fall	6-8	#: Growth conditions vary widely in MT. Dates: Mowing delayed until after July 1 to let desirable species time to mature and reproduce.
NE	No	Yes	Yes	1-2 in W NE, up to 3 in E.	May-Oct	5	#: Less rainfall, shorter growing season, different species in Western NE requires less mowing cycles. Dates: Mowing delayed until after July 1 in Western NE.
NH	No	No	Yes	1	May-Oct	4-6	#: Budget driven: Low budget years only sightline issues areas mowed, all roads mowed once during adequate budget years.

State	Mowing Same Statewide?[1]			Number of Mowings	Mowing Dates	Mowing Height	Comments
	Number	Dates	Height				
NY	No	No	Yes	3 on Interstates, 2 on other rds.	Apr-Dec	4	Dates: Variable geographically due to climate. Mowing delayed in some areas until July or Aug to accommodate ground nesting bird species.
NC	No	No	Yes	Variable	June-Fall	4	#: Variable due to diversity of topography & climate.
OH	No	Yes	No	3	Pre-Memorial Day toPost Labor Day	6-8	#: Typically 3 but more in some areas due to public expectations. Height: Typically the mowing height is 6 to 8" but the grass may be mowed shorter in urban areas.
PA	No	No	Yes	3-4	Mar-Nov	4-8	#: 3 in most areas, 4 in urban and warmer areas.
TX	No	No	No	2 rural, 3 urban	Jan-Dec	5-7	Dates: Mowing can occur during any month due to variations in climatic conditions in TX. Height: 7" rural, 5" urban.
UT	Yes	No	Yes	1	Variable	6	Dates: Variable due to variation in climates in UT.
WA	No	No	Yes	Variable	May-Sep	6-8	#: West of Cascades requires mowing, east does not.
WI	Yes	Yes	Yes	1	May-July 4	6	#: Additional mowing is done for safety reasons. Dates: Start mowing when grass reaches 12" but most mowing must stop by July 4.

[1]Answers based on the following 3 questions:
1. Is the recommended number of times you mow per year the same throughout your state?
2. Are the recommended dates of mowing the same throughout your state?
3. Is the recommended height of mowing the same throughout your state?

[2]Pooled fund member states are underlined and highlighted in yellow.

3.5 Best Management Practices/Recommendations

The vast majority of roadside vegetation best management practices and recommendations address improved safety, promotion of drainage, control of noxious and nuisance weeds, and promotion of desirable natural vegetation. One of the highest priorities for mowing near roadways is to maintain sight distance so motorists can observe and avoid other vehicles, animals or pedestrians, and to be able to read road signs. Trees are removed from near roadways to prevent them from growing large enough to become a hazard to vehicles that leave the road. Best management practices and recommendations that specifically address deer and other wildlife, based on results from this survey, are comparatively rare and largely limited to two categories: (1) restricting the timing of mowing to protect ground nesting birds, and (2) selection of plants to revegetate roadsides that are less likely to attract large animals which may cause potential safety hazards to motorists.

Restricting the timing of mowing to protect ground nesting birds was a best management practice in a number of states. Legislation in Iowa and Michigan delayed mowing until after July 15th on many of the areas to be mowed in an effort to improve nesting success for ring-necked pheasants and other ground nesting birds. Wisconsin only permitted mowing in the clear zone beyond the shoulder cut after July 4th due to concern for ground nesting birds. The timing of nesting for ground nesting birds can vary due to environmental and climactic conditions and it would be recommended to coordinate the establishment of delayed mowing programs with the state's wildlife agency to ensure proper timing.

The selection of plants for revegetating roadsides that do not attract deer or other large herbivores was the topic of discussion for a number of states during the survey process. However, surprisingly Minnesota was the only state of 24 surveyed that indicated that they actually had a list of recommended plants for roadside revegetation that are less likely to attract deer or other large herbivores. Georgia indicated that they discouraged the planting of certain oaks that have acorns that are especially attractive to deer. New York and Washington indicated that they avoid planting clover along roadsides because of its known attraction to deer. Texas indicated that it was looking for alternative cool season temporary covers to replace wheat and oats.

Best management practices for roadside vegetation management as it relates to DVC appear to be more conjectural than documented based on results from this survey. Strong opinions were expressed by DOT personnel during this survey supporting all three possible outcomes (increasing, decreasing, or no effect) with regard to potential impacts of reduced mowing on the number of DVC; however, supporting data was lacking. We found no evidence from this survey that a demonstrated (quantified) reduction of DVC rates had been documented in any state due to changes in roadside vegetation management policies, including reduced roadside mowing. That does not mean a relationship does not exist, of course, but there is clearly a need for further study to document what relationships do exist between vegetation management policies and rates of DVC.

Briefly

- Best management practices for roadside vegetation management as it relates to DVC appear to be more conjectural than documented
- There is clearly a need for further study to document what relationships do exist between vegetation management policies and rates of DVC

4.0 TASK 4 RESULTS: ANALYSIS OF THE EFFECT OF REDUCED MOWING ON DVC RATES

4.1 INTRODUCTION

The primary objective of Task 4 was to determine if reducing roadside mowing causes a measurable change (increase or decrease) in DVCs. A common perception is that decreased mowing may change vegetation structure and/or composition which could affect deer movements, behavior, and/or density, attracting deer at the roadside, and/or motorists' ability to detect and avoid deer entering the roadway. Both of these effects would be expected to increase the DVC rate. However, the results of Task 1 and task 2 indicated that no quantitative evaluation of reduced-mowing on DVC rate has been conducted.

Primary Objective

Determine if reducing roadside mowing causes a measurable change (increase or decrease) in DVCs.

The effect of reduced mowing on DVC rates could be tested experimentally or through a retrospective analysis of existing data. An experimental approach would entail identifying roadway sections with similar attributes (e.g., number of lanes, traffic volume, and roadside land use), assigning them as experimental or control sections, monitoring the DVC rate on all sections for a time period, then reducing roadside mowing along the experimental sections while maintaining the status quo on the control sections. A retrospective approach uses existing data to compare the rate of DVC along the same section of highway before and after reduced mowing. Because multiple years of observation before and after a mowing change are required to examine DVC rate trends, we used the retrospective approach. States with a suitable amount of before and after data available were identified in Task 2, and Maryland and New York were chosen as test cases from this group.

Study Options

- **Experimental Approach**: Studying data from experimental and control sections of selected roadways)
- **Retrospective Approach**: Compare data from same roadway before and after reduced mowing.
- Retrospective Approach was chosen, using before/after data from Maryland and New York.

4.1.1 PROJECT APPROACH

We compared the number of DVC/year before and after mowing was reduced to determine if there was a statistically significant difference between the two time periods. We followed this simple comparison of before/after data with an examination of the predictive relationship of mowing regime to DVC rate, as well as the relationship of DVC rates to Average Annual Daily Traffic (AADT) volume and annual buck harvest, a proxy for deer population size. As discussed in Section 4.5, DVC are known to be correlated to AADT and deer population size.

We conducted our analysis at two scales: 1) the roadway section; and 2) county-wide. A change in mowing regimes will not affect the vegetation in all locations along a roadway equally. The width of the mowed area is defined by the roadway design and varies along most roads. Additionally, steep slopes (e.g., many cut and fill slopes) are never mowed under any mowing regime for safety reasons. We

Study Hypothesis

The impact of reduced mowing would be greatest along roadway sections where the mowing change affected the greatest width of ROW.

hypothesized that the impact of reduced mowing would be greatest along roadway sections where the mowing change affected the greatest width of ROW. We asked local State DOT personnel to identify roadway sections with the greatest amount of previously mowed area affected by the mowing change. We also analyzed county-wide data. We assumed that a county would encompass multiple roadway sections where the mowing change created a change in roadside vegetation structure, and that those changes would be reflected in the county-wide DVC rate. Changes in county-wide DVC rates may provide a more reliable indication of DVC trends, as these larger sample sizes should be less susceptible to random variation, as compared to individual roadway sections. Additionally, we were also interested in examining if changes in the DVC rate were apparent at only one scale or the other.

Because a change in DVC rates is a safety issue, we approached our analysis from a safety perspective. When transportation safety analysts examine the efficacy of a roadway safety improvement project, it is standard practice to compare three years of crash data from before the improvement to three years of data from after the improvement to determine if the improvement had any effect (e.g., Persuad 2002, Hauer 2001). Three years of pre- and post-treatment data are considered to provide an acceptable trade-off between collecting enough data to detect a statistically significant change, and minimizing temporal effects that can influence the crash rates independent of the safety improvement being analyzed. Crashes are rare events, and less than three years of data are unlikely to provide statistically sufficient sample sizes. However, longer time periods are likely to encompass other roadway and development projects, changes in driver behavior, and/or changes in traffic volume, which can independently influence crash rates and mask the effect of the roadway change being analyzed.

Time Span of Data Collection

Three years of pre- and post-treatment data are considered to provide an acceptable trade-off between collecting enough data to detect a statistically significant change, and minimizing temporal effects that can influence the crash rates independent of the safety improvement being analyzed.

4.2 STUDY AREAS

Maryland and New York are part of the group of nine states that contribute to the Deer Vehicle Crash Clearing House Pooled Fund. All Pooled Fund members have changed their mowing policies since 2000, except for Minnesota, which last changed its policy in 1989. Iowa, Ohio, and Texas changed their policies in 2010, so three years of post-treatment data is not yet available for analysis. New Hampshire changed its policy in 2004, New York changed in 2008, and Maryland, Connecticut, and Wisconsin changed their policies in 2009.

Maryland and New York were chosen for study because these two states met a number of criteria:

- Maryland reduced roadside mowing in 2009 and New York reduced mowing in 2008 (see below), making three years of before and after data available. As discussed above, standard safety data analysis practice is to compare three years of pre-treatment data to three years of post-treatment data to detect a treatment difference.

Criteria for States in Study

Maryland and New York were chosen for the study because:

- Three years of before and after data
- Members of the Pooled Fund
- In Climatic zone where vegetation grows quickly and mowing change will have a rapid measurable impact
- DVC data readily available

- Maryland and New York are contributing members of the Pooled Fund.
- Maryland and New York are located in a climatic zone where vegetation grows quickly and a change in mowing regime would be expected to rapidly have a measureable impact on the structure (e.g., height) of ROW vegetation.
- DVC data was known to be readily available from the Maryland State Highway Administration (MD SHA) and the New York State Department of Transportation (NYSDOT).

Maryland changed its mowing program in 2009, from 4-6 full cuts of the entire mowable area within the ROW from May through October, to two full cuts with up to four single passes along the shoulder from May to October. The assumed effect of this change would be longer periods of taller grass in ROW sections where the mowable areas are wider than a single mowing pass would cover (ca. 15 feet).

New York changed its mowing program statewide in 2008, but note that Region 6 reduced its mowing program in 2004. The change can generally be described as a change from 2-3 full cuts of the entire mowable area within the ROW between May and December, to a single full cut with one or two additional cuts of the clear zone only. The assumed effect of this change would be longer periods of taller grass in ROW sections where the mowable areas are wider than the clear zone (ca. 15-30 feet).

As discussed in detail in Section 4.5, the location and rate of DVCs are affected by a wide range of variables from the roadway and the adjacent landscape. However, reliable data describing changes to the roadway and adjacent landscape are generally not available. In response to the lack of data, we assumed that that there were no changes to the roadway within the study area during the study period. To minimize landscape sources of variation, we looked for study areas that likely experienced relatively low amounts of land use change during our study period. In Maryland, we specifically focused on MD SHA Region 6 (Figure 1, Appendix A), which consists of Allegany, Garrett, and Washington Counties, the western most part of Maryland. This part of Maryland is largely forested, minimizing the potential for changes in agricultural land use. The human population growth and subsequent changes in land use from 2006 through 2011 were also determined to be minimal in Allegany and Garrett Counties , which both recorded less than one percent population growth from 2000 to 2010 (US Census Bureau, 2011). Washington County reported an 11% rate of growth for 2000-2010, but the road section used from this county (see below) is rural and aerial photography (Google Earth, 2012) indicates that land use around it remained consistent in from 2006 through 2011. In New York State, we simply requested roadway sections located in rural areas, and were directed to roadway sections in Allegany and Columbia Counties (Figure 2, Appendix A), which experienced a -2.0% and 0.0% rate of population growth respectively, from 2000-2010 (US Census Bureau, 2012).

Criteria for Study Area

Areas that likely experienced relatively low amounts of land use change during our study period:

- Maryland study area is largely forested.
- New York roadway sections in rural areas with zero or negative population growth from 2000 to 2010.

To identify roadway sections with large areas of previously-mowed ROW that were now mowed less frequently, we contacted maintenance personnel at both State DOTs. In Maryland, we contacted the Region 6 Assistant District Engineer (ADE). We asked the ADE to identify roadway sections in District 6 in rural settings with large mowable areas that experienced a noticeable change in roadside vegetation as a result of the change in mowing policy. The ADE in turn requested that maintenance personnel identify roadway sections meeting the requested criteria, and we relied on their judgment to provide suitable roadway sections. In New York we contacted the Vegetation and Environmental Program Manager in the NYSDOT Office of Transportation Maintenance. We asked the Program Manager to identify roadway sections in rural settings with large mowable areas that experienced a noticeable change in roadside vegetation as a result of the change in mowing policy. The Program Manager in turn requested that regional Resident Engineers identify roadway section meeting the requested criteria, and we relied on their judgment to provide suitable roadway sections.

For Maryland, District 6 provided six possible locations that varied in length from less than 0.2 miles to 7.1 miles in length. The two smallest sections were associated with a major interchange (I-68 and MD 219) and were dropped from consideration due to their small size and difficulty of interpreting crash locations associated with an interchange. The four roadway sections considered for analysis were:

- MD 36 – MD36/MD 47 intersection east to the MD36/MD35 intersection (3.0 miles; Allegany County)
- US 220 – US 220/I-68 interchange north to the MD/PA state line (3.7 miles; Allegany County)
- US 219 – Deep Creek bridge north to US 219/MD 42 intersection (3.8 miles; Garrett County)
- MD 67 – Mile post 5.1 north to MP 12.2 (7.1 miles; Washington County)

For New York, Region 6 provided one possible location, and Region 8 provided two. All three locations were of a suitable length, and were considered for analysis. These locations were:

- I-86 – The entire length of I-86 within Allegany County (34.4 miles)
- Taconic State Parkway (TSP)- from RM 113.8 to RM 118.9 and from RM 126.7 to 131.6 (Columbia County; 10.0 miles total)

In addition to these six roadway sections, we also considered county-wide data from four of the counties in which these roadway sections were located, for a total of ten study areas. The counties considered consisted of Allegany and Garrett Counties in Maryland (Region 6), and Allegany (Region 6) and Columbia (Region 8) Counties in New York. As described above, these four counties had a growth rate of 1% or less during the 2000-2010 period, meeting an assumption of minimal land use change during the study period reasonable. Washington County was not considered as it had a growth rate of 11%.

4.3 DATA AND METHODS

As described in Section 4.1 above, we consider three types of variables in addition to mowing regime for our analysis. The number of DVC/year in a study area was the dependent variable, and AADT, buck harvest size, and mowing regime were the independent variables we tested for their influence on the DVC rate. These data and their sources are described in detail below.

Variables Considered in Study

- DVC per year
- Mowing regime
- Average Annual Daily Traffic (AADT) volume
- Annual buck harvest (a proxy for deer population size)

4.3.1 DVC Data

Maryland and New York collect DVC data through their crash reporting systems. Crash reports are generally filed only when damage (to property or injury to vehicle occupants) warrants a call to the police. Therefore, crash data is known to underreport the actual number of DVC that occur (Conover et al. 1995, Romin and Bissonett 1996), but it does provide a reasonable index of DVC, and is widely used for a variety of DVC analyses (Huijser et al. 2007). Carcass data also provide another index of DVC, though it is also an undercount because many deer leave the roadside before dying and some carcasses are salvaged. Currently, all states have standardized crash reporting systems in place, while only a few states have standardized carcass recording programs.

The State of Maryland Motor Vehicle Crash Report has a code for collision “with animal,” and DVC are coded as such and entered into Maryland’s crash data base. The New York State Department of Motor Vehicles Police Accident Report form has codes for collision “with animal” and “with deer,” and DVC may be coded as either at the discretion of the responding officer and entered as such into New York’s crash data base. The majority of “with animal” crashes are known to be DVC. In both states, these data are then compiled by the DOTs’ respective Safety programs, and are available by date and location, upon request. In addition to crash data, Maryland also systematically collects data on the location of deer carcasses removed from the roadway. The MD SHA Office of Maintenance has been using the Large Animal Removal and Reporting System (LARRS) to record the location of all deer (and other large animal) carcasses removed from the road by maintenance personnel since 2001. All carcass locations recorded using the LARRS are entered into a GIS data base that is maintained by the SHA Office of Maintenance, and these data are also available upon request.

Compiling the Data

- Maryland Motor Vehicle Crash Report has a code for collision “with animal,” and DVC are coded as such.
- The New York State Department of Motor Vehicles Police Accident Report form has codes for collision “with animal” and “with deer,” and DVC may be coded as either at the discretion of the responding officer.

For Maryland, we requested deer carcass data for 2006 through 2011 from the LARRS database for the four roadway sections chosen for study, as well as county-wide data for Allegany and Garrett Counties. We opted to use the LARRS data as typically more roadkill locations are recorded then crashes are reported. Using LARRS data helped to ensure the sample size for the relatively short focal roadway sections in Maryland would be adequate. For comparative purposes, we also requested county-wide DVC data from the crash data base. These data were only available for 2006-2010. Both data sets contained the county, route number, location (MP) and year for each carcass or DVC record. We sorted the records by route and year to determine the annual number of DVC on each focal road section and in each county of interest. For New York, we requested and combined “with deer” and “with animal” crash data for Allegany and Columbia Counties for 2001 through 2010 identified by date and location. We received statewide data and sorted these data by county and roadway section to identify county-wide and focal roadway section data sets for analysis.

4.3.2 AADT Data

Traffic volume and all types of crashes are correlated, including DVC. To examine the relationship of AADT to DVC in our study areas, we acquired AADT counts for the focal roadway sections and county-wide. For Maryland, 2006-2011 AADT data were available from MD SHA's on-line traffic volume maps for the four focal roadway sections (MDSHA 2012). Traffic counters are located at roughly the beginning and end of the MD 36 and MD 67 focal roadway sections, and the average of the two reported annual values was calculated and used for subsequent analyses. US 220 and US 219 both had only a single counter, located near one end of the section of interest. For the county-wide data, we averaged the AADT from all counters that reported a count for every year of the study period. Data was only available in an electronic spreadsheet format for 2006-2010. For New York, we requested AADT data from the NYSDOT Traffic Data Services Bureau, and received state-wide traffic count data from 1996 through 2010, with counters reported by county and road section. We sorted the data by location and year. For the I-86 focal sections, we averaged the seven counters along that section of roadway; for the TSP focal section we averaged the three counters along it. For the county-wide data, we averaged the AADT from all counters that reported a count for every year of the study period.

4.3.3 Harvest Data

All other things being equal, DVC should be more common when deer are more common. Because deer populations are notoriously difficult to count or estimate, buck harvest rates are commonly used as a proxy for deer population numbers. Generally, the number of buck permits available to hunters is nearly constant, and in the short term (i.e., 10 year increments) hunter effort appears to remain relatively constant. Therefore, fluctuations in the buck harvest should approximate fluctuations in the number of deer present across the landscape. Although the Maryland DNR does estimate deer populations (in part based on buck harvest statistics) the NYSDEC does not, and for consistency, we opted to use buck harvest data as a proxy for deer population in both states. We acquired 2006 - 2011 county-wide buck harvest rates for Allegany and Garrett Counties in Maryland from the Maryland Annual Deer Report (MD DNR 2006-2011). For Allegany and Columbia Counties in New York we acquired the 2007-2010 data from the New York State White-tailed Deer harvest Summary (NYSDES 2007-2010), and directly from the NYSDEC for 2001-2006. Note that the New York 2003 harvest statistics were unavailable.

A Proxy for Deer Populations

Buck harvest rates are commonly used as a proxy for deer population numbers.

- The number of buck permits available to hunters is nearly constant.
- In the short term (i.e., 10 year increments) hunter effort appears to remain relatively constant.
- Therefore, fluctuations in the buck harvest should approximate fluctuations in the number of deer present across the landscape.

4.3.4 Analysis Methods

Each study area represented one data set, and each data set had three years of "before" and three years of "after" data, for a total of six observations/study area. Each observation contained four variables, consisting of the number of DVC/year, AADT, annual county-wide buck harvest, and mowing regime ("typical" or "reduced"). We began by plotting the DVC, AADT, and harvest data independently for all study areas using Excel charts, and examined the results visually for apparent trends in each of the variables across the six-year study period.

> **Defined**
>
> **Wilcoxon Rank Sum Test**: A non-parametric statistical hypothesis test to compare the probability distributions for measurements taken from two independent samples.

We used the Wilcoxon Rank Sum test to compare the number of DVC/year before and after mowing was reduced to determine if there was a statistically significant difference in the average number of DVC/year between the mowing regimes. We used this non-parametric test because of the small sample sizes. After the simple comparison of before/after data, we examined the predictive relationship of mowing regime on DVC rate, as well as the relationship of AADT and annual buck harvest to DVC rate. These relationships were examined for each data set separately by regressing DVC against each of the other variables and examining the significance of the generated R2 value. As a precursor to this analysis, the normality of the variables in each data set was examined using the Shapiro Wilk test. We used this test as it is known to be appropriate for small sample sizes. All statistical tests were implemented using a statistical package for the PC (Statistix 7, Analytic Software 2000).

4.4 RESULTS

4.4.1 UNDERLYING TRENDS – MARYLAND

In Maryland, mowing was reduced in 2009. During the 2006-2011 study period, DVC rates in the six Maryland study areas generally increased from 2007 through 2009, then declined again though 2011 (Figures 3 and 4, Appendix A). AADTs in all study areas varied by less than 10% over the study period, and were generally higher in the 2006-2007 portion of the study period (Figures 5 and 6, Appendix A). Buck harvest varied by 30 % in Allegany County and 7% in Garret County across the six-year study period, and was generally highest in the 2006-2008 portion of the study period (Figures 7).

4.4.2 UNDERLYING TRENDS – NEW YORK

The study periods in New York differed by county, due to Regions 6's early implementation of reduced mowing practices. Mowing was reduced in 2004 in NYSDOT Region 6, and DVC rates in the Allegany County and I-86 study areas trended upward throughout their 2001-2006 study period, with the highest rates occurring in 2006 (Figures 8 and 9, Appendix A). Mowing was reduced in 2008 in NYSDOT Region 8, and the DVC rates in the Columbia County study area trended upwards but remained relatively flat in the TSP study area across their 2005-2010 study period (Figures 8 and 9, Appendix A). AADTs varied from 1% to 6% across the six-year study periods in the four New York study areas, and did not show a consistent trend between the Allegany County and I-86 study areas (Figures 10 and 11, Appendix A) or between the Columbia County and TSP study areas (Figures 10 and 11, Appendix A). Buck harvest varied by 53% in Allegany County and 14% percent in Columbia county (Figure 12, Appendix A).These larger difference are due in part to an apparent dramatic decrease in New York State's deer population in the early 2000's, which now appears to be rebounding. This statewide trend is reflected in the harvest trends from the two study periods, with the highest harvest rates in Allegany County reported in 2002, and the highest rates in Columbia County reported in 2008.

4.4.3 Comparison of DVC Before and After Mowing Reduction

The average DVC/year in the three years before and the three years after mowing was reduced is reported in Table 6 by study area. Five of the study areas reported more DVC/year after mowing was reduced, four study areas reported fewer DVC/year after mowing was reduced, and one study area experienced essentially no change. The results from three of the New York study areas were marginally significant (p =0.10), but the direction of the changes was inconsistent. None of the Maryland study area changes were significant.

Table 6. Summary of results by study area

	New York				Maryland					
	Allegany	Columbia	I-86	TSP	Allegany	Garrett	US220	MD 36	US 219	MD 67
DVC Before[1]	159.0	365.0	22.7	**24.7**	311.3	**531.3**	8.7	1.7	**13.7**	**12.7**
DVC After[1]	**191.7**	**583.0**	**36.3**	18.0	**382.7**	434.3	8.3	**2.7**	9.0	11.7
WRS p-value[2]	0.2	0.1	0.1	0.1	0.8	0.4	0.8	0.7	0.4	0.6
R2 AADT[3]	0.0365	0.6957	0.3296	0.3485	0.1819	0.3552	0.2854	0.3195	0.2624	0.1362
R2 Harvest[3]	0.7019	0.0628	0.3136	0.3642	0.0587	0.5146	0.0661	0.0234	0.0151	0.0005
R2 Mow[3]	0.4681	0.9171	0.4522	0.4237	0.2330	0.1699	0.0034	0.2195	0.2130	0.0177

[1]Average DVC/year at each location before and after mowing was reduced. Greater average DVC/year are in **bold**.
[2] Wilcox Rank Sum test p-value. Values smaller than 0.05 indicated that central values of the two samples are significantly different
[3] R^2 value of the regression of the variable against annual DVC.

Results of the Shapiro Wilk normality tests indicated that the variables examined were normally distributed accept for AADT; four of the Maryland and one of the NY study area AADTs had significantly non-normal distributions. Table 7 reports the strength of the three tested variables in predicting the number of DVC in a study area, based on the significance of their R^2 values (which are reported in Table 6). In only three of 30 cases was the p-value significant, results which would be expected by chance. In general, the R^2 values for AADT were higher and the values for Harvest were lower (Table 6), but these trends should be interpreted with care due to the non-normality of some of the AADT data and due to the small sample sizes in general.

Table 7. Significance of the relationship of all variables considered with annual number of DVC, by location*

AADT		Harvest		Mow	
Study Area	p-value	Study Area	p-value	Study Area	p-value
NY Allegany	0.72	MD 67	0.97	US 220	0.91
MD Allegany	0.47	MD Allegany	0.93	MD 67	0.80
MD 67	0.47	US 219	0.82	MD Allegany	0.63
US 219	0.30	MD Garrett	0.79	US 219	0.36
MD Garrett	0.29	MD 36	0.77	MD 36	0.35
US 220	0.27	NY Columbia	0.63	MD Garr	0.23
MD 36	0.24	US 220	0.62	TSP	0.16
I-86	0.23	I-86	0.25	I-86	0.14

AADT		Harvest		Mow	
Study Area	p-value	Study Area	p-value	Study Area	p-value
TSP	0.22	TSP	0.20	NY Allegany	0.13
NY Columbia	**0.04**	NY Allegany	**0.04**	NY Columbia	**0.01**

*Significant values (less than 0.05) are in **bold**.

4.5 Discussion

In general, there was little evidence to suggest that the mowing regime had a significant effect on the number of DVC observed within the ten study areas. None of the differences in the average annual number of DVC before and after reduced mowing was significant at any of the study sites (Table 6). Additionally, the direction of change in DVC numbers (increase or decrease) was inconsistent, showing no clear trend across all study sites, although there was a tendency for more DVC to occur county-wide after mowing was reduced (Table 6). The R^2 values between DVC and mowing were significant for only one of the ten study area (Table 7). However, it should be noted that neither of the other two variables tested, both widely demonstrated to be correlated with DVC rates as discussed below, appeared to have a strong relationship with the DVC rate either.

Briefly

In general, there was little evidence to suggest that the mowing regime had a significant effect on the number of DVC observed within the ten study areas.

The data were tested using a method that made no assumption regarding normality and is deemed to be appropriate for small samples sizes. However, it should be noted that safety data analysts have recognized the limitations of traditional statistical tests in finding true difference between the small sample sizes that are typically available for crash data, and that were used for the focal roadway sections, particularly the Maryland sections. In response to these limitations, Empirical Bayes (EB) methods have been developed to predict the expected future rate of crashes at a given location. These predictive equations rely on a location-specific Safety Performance Factor (SPF) that is generated from historically crash rates using computationally intensive methods, and location-specific AADT values. Generating DVC-specific SPFs for the focal roadway sections used in this analysis was beyond the scope of this project.

Defined

Empirical Bayes Methods: A class of methods which use empirical data to evaluate / approximate the conditional probability distributions that arise from Bayes' theorem. These methods allow one to estimate quantities (probabilities, averages, etc.) about an individual member of a population by combining information from empirical measurements on the individual and on the entire population.

Applying an EB approach to the small before/after DVC samples from the focal roadway sections might have provided different results for this study. However, it should be noted that EB methods are being adopted to examine crash “hot spots” (i.e., locations that have an excessive number of crashes), in part to determine if these hotspots are simply occurring due to chance. The focal roadway sections used for this analysis were not hotspots, and therefore their DVC rates may be expected to experience less random variation over time and be more reliably examined using tradition statistical methods. Applying the EB approach to the county-wide data would not likely have provided different results as the spatial extent of the county-wide study area should dampen random variation in DVC rates.

The lack of a demonstrated relationship between DVC rates and the reduction in mowing could stem from a variety of causes. Most simply, there may be no significant relationship, or the effect is so small that it cannot be readily detected. DVC are known or assumed to respond to a large number of variables from a variety of sources that can vary across space and/or time. Some are associated with the roadway, while others are a function of the surrounding landscape; some have the potential for substantial temporal variation while others do not. All have the potential to mask or swamp the effect of any other given variable. The roadway, roadside, and landscape variables that are known to affect DVC rates along a given section of highway are summarized in Table 8.

Additionally, the reduced mowing practices in the study areas are incremental; clear zones from 15 up to 30 feet directly adjacent to the roadside are mowed on the same schedule as previously, and annual full cuts maintain all mowable areas as non-woody vegetation. The major difference between the roadside vegetation before and after mowing was reduced appears to primarily be longer periods of taller grass, with potentially some increase in the forb component of the mowed vegetation outside the clear zone. White-tailed deer feed primarily on woody vegetation, but also forbs in spring and early summer. A change in the structure of the grassy vegetation and marginal increase in the forb component would not be expected to substantially increase the number of deer that may already be using the roadside to some degree. If a change in vegetation in some areas did attract deer, the limited size of these areas would be likely to cause a minor, seasonal shift in the distribution of deer across the landscape, as these areas would be only a small portion of any given animal's home range. Likewise, the maintained clear zones should provide motorists with sufficient visibility to observe deer entering the roadway.

Impact of Mowing on Roadside Use by Deer

- Reduced mowing appears to result in longer periods of taller grass with potentially some increase in the forb component.
- White-tailed deer feed primarily on woody vegetation, but also forbs.
- A change in the structure of the grassy vegetation and marginal increase in the forb component would not be expected to substantially increase the number of deer that may already be using the roadside.

The lack of a relationship between DVC rates and AADT and deer harvest was somewhat unexpected. All types of crashes increase as AADT increase, as more traffic creates more exposure. However, in all ten study areas changes in AADT were small across the study period, and because DVC are relatively rare events, DVC rates may not be sensitive to such small amounts of variation. Numerous authors have demonstrated a predictive relationship between the size of deer harvests and DVC rates (e.g., Farrell and Tappe 2007, Jaarsma et al. 2006,McShea et al. 2008, Romin and Bissonette 1996, Seiler 2004, McCaffery 1973). However, these relationships are often reported for variations in harvest sizes across space, or for longer time periods then the six-year analysis period used for this study. Additionally, AADT and the number of deer across the landscape likely interact with each other, as well as with many other variables (Table 8), potentially making the relationship of a single variable with DVC rate difficult to detect.

Table 8. Variables determined to have a significant relationship with DVC locations, based on a review of 16 studies.*

Source	Variable	Scale**	Positive	Negative
Land Use	Number of buildings	Local		1, 10, 13
	Human population density/urbanization	Landscape	5, 9, 11	
	Amount of public recreation land	Landscape	6, 13	
	Amount of crop land	Landscape		9, 10, 15
Habitat	Distance to/presence of forest cover	Local	3, 6,10,15	1,16
	Distance to/presence of open cover	Local	1,2,12,14	
	Amount/contrast of habitat edges	Landscape	5	
	Amount of forest cover	Landscape	5, 10	7
	Habitat diversity	Landscape	6, 10	
Topography	Topography that slopes to the road	Local	2, 3	16
	Drainages/riparian corridors intersect the roadway	Local	6, 15	
	Number of drainages/bridges	Landscape	8	
	Slope of adjacent land	Landscape		16
Roadway	Line of sight	Local	1	
	Fencing – amount or type	Local		1
	ROW fence located near a forest edge	Local	14	
	Guardrails/Jersey barrier	Local		10, 16
	Crossroad	Local		10
	Pavement width	Local		16
	Roadway type (2-lane state highway)	Landscape	7, 11	
Traffic	Traffic Volume	Landscape	5, 11, 15	
	Posted speed limit	Local	12, 15	1

* The numbers in the columns denoting a Positive or Negative association between a variable and DVC numbers, correspond to the references listed below. A positive association means that DVC were more likely to be present when that variable was present, or when the value of that variable was larger. A negative association means that DVC were more likely to be present when that variable was not present, or when the value of that variable was smaller.

**Local scale - generally within 300-800 feet of the pavement's edge; Landscape scale - generally from within 0.5 miles of the roadway up to the entire county which the roadway is situated in.

1. Bashore et al., 1985
2. Bellis and Graves, 1971
3. Biggs et al. 2004
4. Bissonette and Kassar 2008
5. Farrell and Tappe 2007
6. Finder et al., 1999
7. Grovenburg et al. 2004
8. Hubbard et al., 2000
9. Iverson and Iverson, 1999
10. Malo et al. 2004
11. McShea et al. 2008
12. Ng et al. 2008
13. Nielsen et al., 2003
14. Puglisi et al., 1974
15. Romin and Bissonette, 1996
16. Singleton and Lehmkuhl 2000

4.6 Future Research

The most robust way to examine the contribution of mowing regime to DVC rates would be to experimentally vary mowing regime as part of a Before-After-Control-Impact (BACI) study design. With this approach, variations in the DVC rates in the control areas can be used to account for the effect of other variables that could influence DVC rates. This approach would entail monitoring the DVC rates in the control and impact sections for a time period, changing the roadside mowing regime along the impact sections while maintaining the status quo on the control sections, monitoring the DVC rates for another period of time, and then comparing results. Because DVCs are relatively rare events, a minimum of three years of before and after data would likely be needed to for adequate samples size and to minimize the influence of random variation.

To account for the influence of other variables, all roadway sections under study and the adjacent landscape would need to be monitored for changes to variables known or hypothesized to contribute to the DVC rate (Table 8). This would include variations of AADT, and all changes to roadway features (e.g., pavement width, placement and type of guardrails/Jersey barrier, signage) and the local landscape (e.g., crop changes and mowing schedules in abutting agricultural fields, new residential or commercial development, changes in recreational use of abutting open spaces). Because accurately monitoring deer population size is impractical, all study roadway sections should be subject to the same environmental factors that influence deer populations (e.g., climate, habitat type, hunting pressure) in order to accurately account for the influence of any changes in deer population size.

The source for DVC data could be crash reports, an existing carcass location recording program, or a carcass recording program implemented specifically for the study. If the crash reporting or existing carcass recording efforts can reasonably be expected to remain consistent during the entire study period, using these data sources would be most cost effective. All state DOTs have consistent AADT monitoring programs in place which can provide reliable traffic volume data. However, programs to consistently track changes to other variables are unlikely to exist. Monitoring these variables would be a specific responsibility of the research project. Identifying changes to these variables could be accomplished through a combination of periodic visits to the study area to observe changes directly, interviews with DOT personnel, analysis of aerial photography, and/or monitoring of local media outlets.

5.0 SUMMARY

<u>Literature Review:</u> Current literature was reviewed and summarized to describe the potential safety, economic, and ecological impacts of roadside vegetation management policies and practices, including reduced roadside mowing. It has been estimated that greater than one million DVCs occur annually in the United States resulting in over 29,000 human injuries, over 200 human fatalities, and over 1 billion dollars of property damage. Two aspects of roadside vegetation management have been hypothesized to increase DVCs: (1) attraction of deer to the highway to feed on roadside vegetation, and (2) the reduction of roadside visibility caused by higher and /or denser vegetation, making it more difficult for motorists to detect and avoid deer on the roadway. In spite of these hypothesized concerns, this literature review was unable to locate any scientific literature that quantified the rate of DVCs anywhere in North America to any aspect of roadside vegetation management policies, including reduced roadside mowing.

The economic impacts of reduced roadside mowing include the anticipated savings form decreased labor and material costs for maintenance associated with a reduction in mowing activities, and the costs associated with any mowing-related rise or decline in the number of DVCs. Based on results from our literature review and our survey of DOTs, seven states reported estimated annual savings ranging from $850,000 to $20 million. Estimated cost for the average deer-vehicle collision was reported in the literature to be about $6,600 in 2007. Accordingly, the statewide annual savings discussed above would cover the costs of approximately 128 to 3,030 DVCs, respectively, assuming a change (reduction) in mowing practices led to an increase in DVCs, as suspected by some. Unfortunately, we were not able to locate any literature that documented a change in DVCs related to any existing reduced roadside mowing policies, and no such data was available from any of the 24 state DOTs that we surveyed in conjunction with this project.

The location, timing, frequency, and height of mowing are all important ecologically as they control the wildlife habitat that develops on the ROW, which in turn determines the distribution, abundance, and composition of wildlife communities that may use the ROW. Mowing regimes that create a more variegated complex pattern and composition of roadside vegetation tend to support greater species richness, while widespread frequent mowing favors the spread of grasses at the expense of most native plants. Recommendations for rotational roadside mowing regimes or maintenance of refuges (areas not mowed) were specifically mentioned in ecological research publications to improve the abundance of waterfowl, pollinating insects, and spiders. A variety of research studies have shown that modifications of roadside vegetation management resulted in increases of targeted animal populations. Adjustments to roadside vegetation management included plantings and changes in mowing frequency and timing, while target species included waterfowl, ring-necked pheasants, bees, native butterflies, as well as birds and mammals in general. With regard to ecological impacts of roadside vegetation management on deer, literature focused primarily on roadside plantings potentially attracting deer, especially in major forested landscapes during times of the year when high-energy mast crops are not available. We were unable to locate any scientific literature from any studies of the ecological impacts on deer specifically from a reduced roadside mowing policy.

Survey: A reduction in roadside vegetation mowing has occurred throughout a majority of the United States in recent years based on results from an email and phone follow-up survey as part of this project. Twenty-one of 24 states (88%) that responded to the survey reported a reduction in their mowing programs. For those 21 states that reduced mowing, 17 did so statewide while 4 reduced mowing in only some parts of their state. The timing of when roadside mowing programs were reduced varied from 1968 to 2010; however, nearly two-thirds (13/21=62%) of the states that had reduced mowing programs made their reductions in the past three years (2008-2010); 81% (17/21) in the past 7 years (2004-2010). Economic concern was the overwhelming reason provided why roadside mowing programs have been reduced in surveyed states with ecological concern being secondary. Ecological concerns included impacts of survival of ground nesting birds, establishment of native plants, and weed control. The nine pooled fund member states appear to be comparable to the rest of the country with regard to reduced mowing policies.

A comparison of “reduced” and “typical” mowing policies for each of the 21 surveyed states that reported a reduced mowing policy involved a combination of changes in the number of mowing cycles per year, seasonal timing of mowing, areas mowed, and/or mowing height. A reduction in the number of mowing cycles and/or areas mowed was reported for all 21 of the surveyed states with “reduced” mowing policies. However, a reduction in mowing height and/or changes in the timing of mowing was less common, involving only 8 of those 21 states. Washington reported that a higher mowing height was advantageous to plant stability and sustainability.

Mowing regimes are typically not the same throughout all areas within most states for a variety of reasons. Mowing requirements are impacted by differences in temperature and rainfall due to changes in latitude, topography, and/or elevation which in turn impacts grass species composition, length and timing of growing seasons, and growth patterns. Different classifications of roads, the location within the Right of Way (ROW) and the purpose of mowing (or not mowing) also impact mowing regimes within a state. Interstate (multi-lane) highways tend to have more mowing cycles than secondary roads. For safety reasons, locations nearest the roadway that may impact sight distance tend to be mowed more frequently than areas beyond the recovery zone. As a rule, there tends to be more mowing cycles, lower mowing heights, and more of the ROW areas mowed in urban areas and other high human use areas, such as rest areas and visitor centers, than in rural areas. Other factors that contribute to a variety of mowing regimes being used within a state are the concern of mortality of ground nesting birds during the nesting season, control of weeds (mowing prior to seed production of weed species), establishment and maintenance of more desirable native vegetation, drought conditions, and fire safety.

Fifteen states indicated that neither a perceived or demonstrated reduction in DVC played a role in current roadside vegetation management policies while nine states reported a perceived reduction. **<u>We found no evidence from the survey that a demonstrated (quantified) reduction of DVC rates had been documented in any state due to changes in roadside vegetation management policies.</u>**

The vast majority of roadside vegetation best management practices and recommendations address improved safety, promotion of drainage, control of noxious and nuisance weeds, and promotion of desirable natural vegetation. One of the highest priorities for mowing near roadways is to maintain sight distance so motorists can observe and avoid other vehicles, animals or pedestrians, and to be able to read road signs. Best management practices and recommendations specifically addressing deer and other wildlife, based on results from this survey, are comparatively rare and largely limited to two categories: (1) restricting the timing of mowing to protect ground nesting birds, and (2) selection of plants to revegetate roadsides that are less likely to attract large animals which may cause potential safety hazards to motorists.

<u>Desktop Study</u>: The desk top study tested the DVC rate as the dependent variable against three independent variables, AADT, annual harvest size, and mowing regime. Although other variables from the roadway and adjacent landscape are known to influence DVC rates, they were not considered as data regarding changes in these variables was not available. For the study areas and time periods analyzed, the results do not indicate that DVC rates are related to mowing regime. To examine the effect of safety improvements on crash rates, safety analysts typically use three years of before and three years of after data to minimize the influence of unrelated, temporal effects on crash rates. This minimal time period was deemed appropriate for DVC study as deer populations are known to respond numerically and behaviorally to a wide variety of variables that change over time. However, small samples like those from the focal roadways may be influenced by random variation and, the results of this analysis should be interpreted with care.

Future research directed at identifying the contribution of mowing regime to DVC rates, if any, should use a BACI approach. A change in mowing regime would be the experimental manipulation applied. A key component of the research would be to accurately record the timing and type of changes to other variables that could influence DVC rates. This would allow the affect of these variables to be accounted for during analysis, and magnitude of mowing regime's influence to be estimated.

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APPENDIX A – TASK 2: LITERATURE REVIEW – FINAL DEER-VEHICLE CRASH, ECOLOGICAL, AND ECONOMIC IMPACTS OF REDUCED ROADSIDE MOWING

TASK 2: LITERATURE REVIEW – FINAL
DEER-VEHICLE CRASH, ECOLOGICAL, AND ECONOMIC IMPACTS OF REDUCED ROADSIDE MOWING

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1.0 INTRODUCTION

Deer-vehicle collisions (DVCs) continue to increase throughout the United States with significant highway safety and economic consequences (Huijser et al. 2009). The number of DVCs occurring in the United States has been estimated at greater than 1 million annually, resulting in greater than 29,000 human injuries, over 200 human fatalities, and over one billion dollars of property damage (Conover et al. 1995).

Roadside vegetation within the right-of-way (ROW) is one of many factors suspected to influence the number of DVCs. Height and density of this vegetation can restrict roadside visibility, making it more difficult for drivers to detect and avoid deer along highways. Also, roadside vegetation with high nutrient value and palatability can attract deer to the roadway (Puglisi et al. 1974, Michael 1980, Feldhamer et al. 1986, Rea et al. 2007).

The amount and frequency of mowing along roadsides appear to be declining for many state departments of transportation (DOT) due to economic or ecological considerations. Virginia, Kentucky, Iowa, Maryland, New Hampshire, Pennsylvania, South Dakota, and Utah have all announced intentions to reduce roadside mowing during 2009 (Dishneau 2009). Most of the states cited economic reasons for roadside mowing reductions; however, South Dakota and Utah reduced mowing to avoid disturbing ring-necked pheasants, sharp-tailed grouse, and prairie chickens during the nesting season. Passage of the Minnesota Mowing Law in 1985 restricted when and where MnDOT could mow along roadsides and resulted in a sharp decrease (32.5%) in roadside mowing between 1984 and 1986 (Varland and Schaefer 1998). This trend of reduced roadside mowing has generated interest on its possible impact on DVCs and highway safety.

The objective of this report is to review and summarize research focused on safety (DVCs), economic, and ecological impacts of reduced roadside mowing and other roadside vegetation management policies. The literature search for this report was conducted primarily using ISI's Web of Science and JSTOR for peer-reviewed journal articles. Google Scholar, websites of universities and organizations active in DVC research, and other internet-based literature search sources were also used and provided both peer-reviewed journal articles and gray literature reports. A summary of results and recommendations of all literature cited in this report is provided in the appendix in Table A-1.

2.0 SAFETY IMPACTS

Over 29,000 human injuries and over 200 human fatalities caused by DVCs are estimated to occur annually in the United States (Conover et al. 1995). Of primary interest to this project is how roadside vegetation management (reduced roadside mowing, planting, cutting woody vegetation) affects DVCs and thus highway safety. Two aspects of roadside vegetation management hypothesized to increase DVCs are: (1) the attraction of deer to the highway to feed on roadside vegetation, and (2) the reduction of roadway visibility caused by higher and/or denser vegetation making it more difficult for motorists to detect and avoid deer on the roadway.

2.1 ATTRACTION OF DEER TO ROADSIDE VEGETATION

There are a number of factors that govern the variation in attractiveness of roadside vegetation to deer. They include the palatability of the roadside vegetation, the timing, abundance and nutritional quality of alternative natural foods available to the deer, landscape vegetation characteristics, and seasonal differences in energy requirements for deer. For example, along Interstate 80 (Puglisi et al. 1974), and Interstate 84 (Feldhamer et al. 1986) in Pennsylvania, evidence of deer being attracted to ROW vegetation was much more pronounced in forested landscapes as compared to agricultural landscapes. This deer movement pattern makes sense nutritionally, because there is less incentive for deer to be attracted to roadside vegetation in agricultural landscapes where high quality foods are typically more ubiquitous and abundant than in landscapes dominated by forest. Likewise, roadside vegetation would be expected to be less of an attractant for deer living in forested landscapes at times when high energy foods such as acorns or beechnuts are abundant, as compared to times when these high energy foods are lacking.

Management decisions on when to cut woody vegetation, when to mow grass and herbaceous growth, or which plants to establish for roadside vegetation all have potential implications for highway safety as these actions affect the quality of forage for deer available on the roadside. Mechanical trimming of woody vegetation during mid-summer has been shown to improve digestibility in subsequent regrowth, making it more attractive to deer (or any other animals that feed on browse) for up to three years (Rea 2003). Managers can, however, impact the quantity and nutritional quality of the woody regrowth by changing the timing of cutting (Jaren et al. 1991, Rea and Gillingham 2001, Rea 2003, Rea et al. 2007). Rea (2003) recommended brush cutting be done early in the growing season, and to avoid brush cutting in the more traditional mid-summer period, to reduce attractiveness to browsing species such as deer.

Prevention of soil erosion, establishment of a clear line of sight along highways, and control of invasive species are important objectives of DOTs when selecting plants for revegetating roadsides after construction projects are completed. Another important consideration for highway safety, especially where deer densities are high, is to select plants that are not preferred by deer. This can present a challenge as candidate plants may not be available that will meet all of the desired objectives, resulting in unavoidable compromises. For example, crownvetch (*Coronilla varia*) is a cool season, hardy, perennial legume particularly well adapted to road bank stabilization, often planted on steep slopes along interstate highway borders in the northeastern United States. However, two studies along interstate highways, one in West Virginia (Michael 1980) and another in Pennsylvania (Feldhamer et al. 1986) reported that white-tailed deer were attracted to crownvetch plantings. Food preferences of deer can vary regionally and seasonally based on availability of other foods. Deer will almost always be attracted to roadsides in spring if that is the first location to "green-up".

Knowledge of the plant species that are preferred or avoided by deer can be helpful in the selection for seeding roadsides. Environmental characteristics specific to the road site such as soil quality, precipitation, seasonal temperature fluctuations, and amount of sunlight are all likely to be important in selecting candidate plants for roadside vegetation establishment. The Minnesota Department of Transportation has developed a "Plant Selector" program (http://dotapp7.dot.state.mn.us/plant/) to assist in the selection of potential roadside plants to match the characteristics of the roadside of interest. The user of this program selects the planting site characteristics (>25 to pick from), the plant characteristics (20 selections), type of plant (tree, shrub, grass, sedge, fern, etc.) and the program makes a selection of plants that meet the criteria entered by the user. Agricultural Extension services of major universities in the geographical area of interest can also often be another good source of this type of information.

2.2 REDUCTION OF ROADWAY VISIBILITY

Roadway visibility changes both temporally and spatially. Obstruction of visibility is greater for deciduous trees and shrubs when their leaves are present during the growing season. The timing of mowing cycles and the stage of growth of grassy/herbaceous areas affect driver visibility and thus may also affect DVC probability. We reviewed five DVC quantitative models that evaluated at least one variable associated with visibility of the roadway as a function of the surrounding vegetation (Bashore et al. 1985, Biggs et al. 2004, Finder et al 1999, Malo et al. 2004, Romin and Bissonette 1996). Only one (Bashore 1985) found roadway visibility to be a significant factor in predicting DVCs However, visibility in these models was not defined using the same approach applied by road safety engineers, and it is unclear if the variables measured have any bearing on a driver's ability to perceive deer on the roadside.

Our literature review uncovered only three studies that explicitly examined any type of animal-vehicle collisions to roadside/railroad visibility or vegetation management: one reported on moose-vehicle collisions in Sweden (Lavsund and Sandegren 1991) and the other two reported on moose-train collisions in Norway (Jaren et al. 1991, Andreassen et al. 2005). All three studies suffered from either experimental design flaws or non-significant results that invalidate their study conclusions for our purposes.

In the moose-vehicle study in Sweden (Lavsund and Sandegren 1991), the treatment involved clearing bushes and removing tree branches below three meters' height in a 20-meter strip along the road. No clearing occurred on the control areas. Reportedly the experiment showed an accident reduction of nearly 20%; however, the significance is questionable as the author did not provide statistical documentation and admittedly stated that this 20% was "very close to a result which might have been expected just due to chance."

Jaren et al (1991) reported on an experiment in Norway where vegetation was removed in a 20-30 meter-wide sector on each side of the railway line, which reportedly caused a 56% (+/- 16%) reduction in moose-train kills (collisions). However, due to several study design flaws, these results are also questionable. First, the treatment and control areas were not comparable. The treated area consisted of two sections that were determined to have "high accident risk" based on a previous four-year study, and the remaining areas (low risk areas) were designated as control areas. The second possible problem in experimental design was that treated and control areas were adjacent. The treatment (removal of vegetation) may have led to moose moving to the control areas, resulting in increased mortality on the control areas. These study design problems are stated in the publication.

Andreassen et al. (2005) reported on an experiment in Norway where a 46% reduction in train-moose collisions occurred in the treated areas; however, there were three treatments (scent-marking, forest-clearing, and supplemental feeding) and due to temporal and spatial differences in the application of the treatments, the effects of forest-clearing alone could not be determined.

We were unable to locate any scientific literature that examined the rate of frequency of DVCs in North America to any aspect of roadside vegetation management policies, including reduced roadside mowing. In the next two phases of this project (Tasks 3 & 4), we will survey DOTs and attempt to obtain suitable DVC data sets to quantitatively measure any differences in the rate of DVCs that might occur between typical and "reduced" roadside mowing areas.

3.0 ECONOMIC IMPACTS

The economic impacts of reduced roadside mowing include the anticipated savings from decreased labor and material costs for maintenance associated with a reduction in mowing activities, and the costs associated with any mowing-related rise or decline in the number of DVCs. We were unable to locate any meaningful estimates of maintenance savings from reduced roadside mowing in the scientific literature. A single report from the popular press indicated that Virginia anticipated a 50% reduction in roadside mowing in 2009 that was estimated to save approximately $20 million (Dishneau 2009). Savings due to reduced roadside mowing will need to be documented on a state-by-state basis in the next phase of this project as we survey the various DOTs. In our evaluation we will determine which states have reduced mowing policies, how each state defines "reduced", and gather budget data to quantitatively document the savings.

With regard to economic impacts of DVCs, we were not able to locate any literature that documented a change in DVCs related to any existing reduced roadside mowing policies. However, we did locate three scientific articles documenting cost estimates for DVCs, all from the same organization (Western Transportation Institute) and by the same senior author (Marcel Huijser). Huijer's original publication, the Wildlife-Vehicle Collision Reduction Study—Report to Congress (Huijser et al. 2007) estimated the average cost of a DVC at $8,388 compared with $6,617 in an abstract presented at the 2009 ICOET Conference (Huijser 2009) and an article published later in Ecology and Science (Huijser et al. 2009). The 2009 ICOET abstract presents the same DVC cost estimates as are presented in the Ecology and Science article and will not be discussed any further here.

Discrepancies between the DVC cost estimates given in the Report to Congress and the Ecology and Science article are a function of changes in values used for calculations based on additional information, and on changes in what was included in the estimates. For example, average vehicle repair costs were adjusted in the 2009 publications based on additional information obtained from State Farm Insurance for 178,500 recent DVC claims. The calculations for human fatality costs were adjusted in the 2009 publications to better reflect the results of studies of the incidence of fatalities in DVCs, and the basis for the monetary value for a deer was changed from hunting and recreational wildlife viewing to just include hunting values. After reviewing the three articles discussed above, we believe the cost estimates provided in the Ecology and Society article (Huijser et al. 2009) would be the best source for calculations for economic impacts of DVCs in this project.

Knowledge of the calculations, assumptions, and supporting evidence for DVC cost estimates is important for DOTs in mitigation programs. A summary of estimated DVC costs, assumptions, calculations, and supporting evidence presented in the Huijser et al. 2009 publication is supplied in Table 1. All estimates are in 2007 US$ using the U.S. Consumer Price Index (U.S. Department of Labor 2008) and are based on Huijser's review of the literature.

Though a reduced roadside mowing policy is anticipated to save money from decreased labor and material costs, as can be seen in Table 1 and from the discussion above, DVC-related costs are substantial ($6,617 per DVC), and even a small change in the rate of DVCs could have a significant effect on the overall costs related to a change in mowing practices.

Table 1. Assumptions, calculations, and supporting evidence for estimated costs (in 2007 US$) for the average deer-vehicle collision (From Huijser et al. 2009).

Description	Cost (US $)	Assumptions and Calculations	Supporting Evidence and Comments
Vehicle repair costs per collision	$2,622	92% of DVCs result in vehicle damage. $2,850 = average repair bill Calculation: $2,850 x .92 = $2,622	90.2% in NS: Tardif & Associates 2003 94% in UT: Romin and Bissonette 1996 $2,850/claim : from State Farm Insurance based on 178,500 DVC claims.
Human injuries per collision	$2,702	5% of DVCs result in human injury 3 types of human injuries occur in the following proportions and estimated costs: 51.4% are classified as "possible" ($24,418 each), 38.4% as "evident" ($46,266 each) and 10.3% as severe ($231,332 each). Calculation: ($24,418 x .514 x .05) + ($46,266 x .384 x .05) + ($231,332 x .103 x .05) = $2,702	2.8% in MI: SEMCOG 2007 3.8% in US Midwest: Knapp et al. 2004 4.0% in US: Conover et al 1995 7.7% in OH: Schwabe et al. 2002 9.7% in NS: Tardif & Associates 2003 Huijser et al. 2007 U.S. Deptment of Transportation 1994 $2,702 estimate includes lost earnings, lost household production, medical costs, emergency services, travel delay, vocational rehabilitation, workplace costs, administrative, legal, and pain and lost quality of life.
Human fatalities per collision	$1,002	Each DVC results in an average of 0.0003 human fatalities. Each human fatality costs $3,341,468. Calculation: $3,341,468 x 0.0003 = $1,002	0.00009 in OH: Schwabe et al. 2002 0.00020 in MI: SEMCOG 2007 0.00029 in NA: Schwabe et al. 2002 0.0003 in Midwest: Knapp et al 2004 0.0005 in NS: Tardif & Associates 2003 U.S. Dept. of Transportation 1994 Huijser et al. 2007
Towing, accident attendance, and investigation	$125	Only 25% of DVCs require these services $500 = average cost for these services. Calculation: $500 x .25 = $125.	Clayton Resources Ltd. & Glen Smith Wildlife Consultants 1989
Hunting value for deer per collision	$116	$441 = average value/deer (2007 US$) 0.61 = hunter success rate for deer $723= value for successful hunting season Calculation: $441/.61 = $723 0.16 = proportion of pre-hunting deer population taken by hunters in US Calculation: $723 x .16 = $116	U.S. Fish and Wildlife Service 2003 U.S. Fish and Wildlife Service 1998 Crete and Daigle 1999
Carcass removal and disposal per collision	$50	Each DVC would require removal and disposal at $50 each.	Can$100: Sielecki 2004 $30.50: for PA contractors or $52.46 for PennDOT: Personal communication Jon Fleming, PenDOT
Total	$6,617		

4.0 ECOLOGICAL IMPACTS

The primary emphasis for this discussion of ecological impacts was to focus on deer and how they might be affected by roadside vegetation management in general, and a reduced mowing policy in particular. After expending considerable effort reviewing the literature, it became obvious that published studies on ecological impacts of roadside vegetation management on deer were unexpectedly scarce. Considering the enormous amount of research that has been conducted on deer, their economic importance, and their prominent role in highway safety, it was especially surprising that ecological research studies of roadside vegetation management impacts on ring-necked pheasants, waterfowl, songbirds, insects and spiders appeared to be more common. Roadside vegetation management decisions have significant ecological impacts on many species other that deer. For that reason we have incorporated a few paragraphs into this memorandum describing results of ecological impact studies of roadside vegetation management on a variety of species other than deer.

4.1 DEER/UNGULATES

We were unable to locate any scientific literature from any studies on the ecological impacts on deer specifically from a reduced roadside mowing policy. We did, however, locate a very limited number of studies that discussed ecological impacts of other aspects of roadside vegetation management that are discussed below.

One ecological impact of roadside vegetation to deer is that it is often used as a source of food. This may be a benefit to deer nutritionally; however, crossing roads to get to the vegetation constitutes a risk of collision with automobiles which is fatal to deer greater than 90% of the time (Allen and McCullough 1976). The selection of plants used to revegetate roadsides, based on their nutritional value and palatability to deer, and the distribution and availability of alternative food sources within the deer's home range are all likely to impact the degree to which deer will be attracted to the roadway. For example, crownvetch, a plant often used for road bank stabilization in the northeastern United States, has been documented to attract deer in West Virginia (Michael 1980) and in Pennsylvania (Feldhamer et al. 1986). Also, where interstate highways intersect major forested landscapes deer have been documented to be particularly attracted to roadside vegetation (Puglisi et al. 1974, Feldhamer et al. 1986) especially during times of the year when high-energy mast crops are not available.

Cutting woody vegetation may also result in regrowth that attracts deer to the ROW. Deer prefer to browse fresh new woody growth, but the seasonal timing of cutting has been found to impact the attractiveness of new growth to herbivores such as deer. Studies in British Columbia found that the timing of brush-cutting influences morphology, phenology, and digestibility of plants for up to three years (Rea and Gillingham 2001, , Rea 2003, Rea et al. 2007). Cutting in mid-summer can result in more digestible regrowth in the following years and may attract deer and other herbivores to the cutting site. Rea (2003) recommended cutting brush early in the growing season to reduce its attractiveness to herbivores. In some cases the timing of pruning may be restricted legislatively. In Texas, for example, due to the Migratory Bird Treaty Act, pruning must occur after October (Personal communication Dennis Markward, TxDOT).

4.2 OTHER WILDLIFE

The location, timing, frequency, and height of mowing are all important ecologically as they control the wildlife habitat that develops on the ROW (Forman et al. 2003), which in turn determines the distribution, abundance, and composition of wildlife communities that may use the ROW. For example, if habitat is created that supports large populations of small mammals (mice, voles, moles, shrews, etc.) and/or ground nesting songbirds, then the ROW is more likely to attract raptors (red-tailed hawk, red-shouldered hawk, American kestrel, etc.) and medium-sized predators such as red or gray foxes, opossums, or skunks. Development of plant communities with abundant blossoms within the ROW has been documented to increase populations of bees (Hopwood 2008), butterflies (Ries et al. 2001), and other pollinating insects (Noordijk et al. 2009), which stimulates pollination in the area and, of course, attracts additional predators of the pollinating insects.

Mowing during late spring and early summer has been documented to cause mortality of young ground-nesting birds and mammals, but this impact can be reduced by delaying mowing until after they have left their nests (Wilkins and Schmidly 1981). For example, Oetting and Cassel (1971) recommended no mowing before July 20 to enhance waterfowl nesting success in duck-producing regions of North Dakota and three ring-necked pheasant research projects in Illinois recommended that roadside mowing be delayed until August 1 to improve nesting success (Joselyn et al. 1968, Joselyn and Tate 1972, Warner et al. 1992).

Mowing regimes that create a more variegated complex pattern and composition of roadside vegetation tend to support greater species richness, while widespread frequent mowing favors the spread of grasses at the expense of most native plants (Foreman et al. 2003). Recommendations for rotational roadside mowing regimes or maintenance of refuges (areas not mowed) were specifically mentioned in ecological research publications to improve the abundance of waterfowl (Voorhees and Cassel 1980), pollinating insects (Noordijk 2009) and spiders (Cattin et al. 2003).

A variety of research studies summarized in Table 2 have shown that modifications of roadside vegetation management resulted in increases of targeted animal populations. Adjustments to roadside vegetation management included plantings and changes in mowing frequency and timing, while target species included waterfowl, ring-necked pheasants, bees, native butterflies, as well as birds and mammals in general.

Table 2. Ecological research studies that have documented modifications of roadside vegetation management that resulted in increases of targeted animal populations.

Ecological Study	Wildlife Species/ Class	State	Treatment/Control	Population Response
Joselyn et al. 1968	Ring-necked Pheasant	Illinois	Treatment: Roadsides seeded to grass-legume mixture and only mowed once per year, delayed until after Aug. 1. Control: Roadsides unseeded (old bluegrass sods and annual weeds), and mowed 3 or more times a year, at least once prior to August 1.	Increased: 3.0 nests/ acre on treatment and 1.5 nests/acre on control area
Hopwood 2008	Bees	Kansas	Treatment: Roadsides restored to native prairie vegetation. Control: Roadsides dominated by weedy, non-native vegetation .	Increased: Restored native prairie supported significantly greater bee abundance and higher species richness
Oetting and Cassel 1971	Waterfowl	North Dakota	Treatment: No mowing in fall to increase cover in the spring. Control: Mowed in fall resulting in less cover in the spring	Increased: Ducks chose unmowed (treated) areas significantly more often and had higher nesting success
Ries et al. 2001	Butterflies	Iowa	Treatment: Roadsides restored to native prairie vegetation with restricted use of mowing and herbicides. Control: Roadsides dominated by weeds (non-native legumes) or non-native grasses with mowing and use of herbicides—traditional roadside mgmt for exotic grassy monoculture.	Increased: 2-fold increase in species richness and 5-fold increase in abundance for habitat-sensitive butterflies.
Roach and Kirkpatrick 1985	Birds & Mammals	Indiana	Treatment: Roadside shrub plantings in plots 328' long. Control: Grassy roadsides	Increased: Numbers of rabbits & birds in shrub test plots were significantly greater.

5.0 COMPARISON OF "TYPICAL" AND "REDUCED" ROADSIDE MOWING POLICIES

We were unable to locate any scientific literature that reported specifically on the safety, economic, or ecological impacts comparing "typical" to "reduced" roadside mowing policies. Additionally, the definition of "typical" and "reduced" roadside mowing is likely to vary from state to state. Confirming these definitions will be part of the next phase of this project (Task 3) when we survey the various DOTs.

Ecologically, one advantage of reduced roadside mowing should be that it will produce less soil/sod disturbance and be more favorable to native plant communities. Another advantage of reduced mowing is that it should also reduce mortality to nesting birds and small mammals in nests, when timed appropriately. One of the possible ecological disadvantages of the reduced mowing policy may be increased chance of fire assuming the amount of dry fuel (dead grass/herbaceous growth) available at the end of the growing season is greater.

With regard to safety, one disadvantage of reduced roadside mowing is the reduced visibility along roadsides, which potentially increases DVCs.

The cost of maintenance (hours and materials) should be less for the reduced compared to the typical mowing policies. However, if DVCs are determined to be higher on highways with reduced mowing, then corrected overall societal costs (which include the cost per DVC= $6,617 from Table 3) may actually be higher for reduced mowing. The actual outcome of this evaluation will be determined when we attempt to quantify DVC impacts of reduced roadside mowing in Task 4 of this project.

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APPENDIX A

Cited References Summarized In Tabular Format

Appendix Table A-1. Summary of cited references on ecological, economic, and safety impacts of roadside vegetation management.

Author	Year	Journal/ Publication	Location	Species/ Class	Impact[1]	Mgmt[2]	Summary of Results/Recommendations
Allen and McCullough	1976	Journal of Wildlife Management	Michigan	White-tailed Deer	E	G	An estimated minimum of 91.5% of white-tailed deer hit by a vehicle died at the scene or shortly thereafter.
Andreassen	2005	Journal of Wildlife Management	Norway	Moose	S	C	Forest clearing and supplemental feeding appears to be reliable ways of reducing moose-vehicle collisions along railways. Found a 46% decrease in moose-vehicle collisions during years with a remedy (forest clearing and supplemental feeding) compared to what would have been expected the same years without any remedy.
Bashore et al.	1985	Journal of Wildlife Management	Pennsylvania	White-tailed Deer	G	G	DVC prediction model for 2-lane PA highways indicated 2 variables (in-line visibility and non-wooded) increased probability of section of highway being a high kill site. Seven variables decreased this probability (residences, commercial buildings, other buildings, shortest visibility, speed limit, distance to woodland and fencing).
Biggs et al.	2004	Southwest Naturalist	New Mexico	Deer	S	G	DVC model that uses a visibility variable which was insignificant.
Cattin et al.	2003	Biological Conservation	Switzerland	Spiders	E	M	Mowing reduces spider populations. Recommends mowing less frequently and leaving some refuges (areas not mowed) in large tracts that will be mowed to reduce impact on spiders.
Clayton Resources	1989	Clayton Resources Ltd.	British Columbia	Ungulates	$	G	Estimates for towing, accident attendance and investigation ranged from Can$100 to Can$500.
Conover et al.	1995	Wildlife Society Bulletin	United States	Deer	$	G	Average vehicle repair bill was $1,577 (in 1995). Estimated 92% of DVCs result in deer fatality, 4% in human injury, 0.029% in human fatality. Estimated > 1 million DVCs occur in U.S. each year costing $1.1 billion in auto repair bills.
Crete and Daigle	1999	Acta Veterinaria Hungarica	United States	Deer	$	G	Reported that deer hunters in the United States harvest an estimated 16% of the pre-hunting deer population.
Dishneau	2009	AP Press Release	United States	General	E, S, $	M	VA, KY, IO, MD, NH, PA, SD, & UT all announced reduction in roadside mowing in 2009. Most states stated economic reasons for the decline but SD and UT reduced mowing to avoid disturbing ring-necked pheasants, sharp-tailed grouse, and prairie chickens during the nesting season. VA reducing roadside mowing by 50%, saving $20 million.
Feldhamer et al.	1986	Journal of Wildlife Management	Pennsylvania	W. T. Deer	G	P	Management efforts to reduce the incidence of road-killed deer should address increasing the effectiveness of deer fence and decreasing the incentive for deer to enter the ROW. >93% of land adjacent to I84 study area was wooded and ROW areas planted with crownvetch attracted deer more so than in agricultural areas.
Finder et al.	1999	Landscape Urban Planning	Illinois	Deer	E, S	G	DVC study with a model for roadside visibility which was determined to be insignificant.

(continued)

Appendix Table A-1. (Continued)

Author	Year	Journal/ Publication	Location	Species/ Class	Impact[1]	Mgmt[2]	Summary of Results/Recommendations
Forman et al.	2003	Book: Island Press	Global	General	G	G	Road Ecology: Science and Solutions is a book that provides a wide background on road ecology issues.
Hopwood	2008	Biological Conservation	Kansas	Insects: bees	E	P	Management of roadside vegetation via planting native species profoundly affected bee communities. Roadsides restored with native vegetation supported significantly greater bee abundances as well as higher species richness compared to weedy (non-native) roadsides. Native regeneration benefits pollinator conservation efforts.
Huijser	2009	2009 ICOET Conference	United States	Deer, elk, moose	$	G	Estimated cost in 2007 US$ for average DVC was $6,617.
Huijser et al.	2009	Ecology and Society	United States and Canada	Deer, elk, moose	$	G	Estimated cost in 2007 US$ for an average DVC was $6,617: $2,622 for vehicle repairs, $2,702 for human injuries, $1,002 for human fatalities, $125 for towing, accident attendance, and investigation, $116 for hunting value of the deer, and $50 for carcass removal and disposal.
Huijser et al.	2007	FHWA Report to Congress	United States	Deer, elk, moose	$	G	Estimated average cost for DVC was $8,388: $1,840 for vehicle repairs, $2,702 for human injuries, $1,671 for human fatalities, $125 for towing, accident attendance, and investigation, $2,000 for monetary value of the deer, and $50 for carcass removal and disposal.
Jaren et al.	1991	Alces	Norway	Moose	S, $	C	Vegetation removal in a 20-30 meter wide sector on each side of the railway line caused a 56% reduction in number of train kills. A cost-benefit analysis indicated a positive economical benefit to treat railway sections with > 0.3 moose-collisions/year.
Joselyn et al.	1968	Journal of Wildlife Management	Illinois	Birds: Pheasant	E	M S	Densities of ring-necked pheasant nests on roadsides that were seeded to a grass-legume mixture and only mowed once after Aug 1 exceeded those on unmowed, unseeded roadside plots mowed once after Aug 1 and on unseeded roadside plots where mowing was not controlled-usually 3 or more times per year.
Joselyn and Tate	1972	Journal of Wildlife Management	Illinois	Birds: Pheasant	E	M S	Number of pheasants hatched on roadsides was substantially increased by the seeding of a grass-legume mixture in place of old bluegrass sods and annual weeds and by delaying mowing until after August 1.
Knapp et al.	2004	Wisconsin DOT	United States	Deer	G	G	3.8% of DVCs resulted in human injuries and 0.03% resulted in fatalities in Midwest.
Lavsund and Sandergren	1991	Alces	Sweden	Moose	S, $	C	Clearing a 20-meter zone on each side of the highway decreased moose-vehicle collisions by almost 20%.

(continued)

Appendix Table A-1. (Continued)

Author	Year	Journal/ Publication	Location	Species/ Class	Impact[1]	Mgmt[2]	Summary of Results/Recommendations
Malo et al.	2004	Journal of Applied Ecology	General	Deer	S	G	DVC model that used roadside visibility in a model that was insignificant.
Michael	1980	WV Dept of Highways	West Virginia	Deer	E, S	P	White-tailed deer appeared to prefer crownvetch planted along an interstate highway in West Virginia.
MN DOT	2010	MN DOT Website	Minnesota	Deer	E	p	Minnesota DOT Plant Selector is a website that provides advice on which plants to use for roadsides based on a variety of characteristics including anticipated deer use. http://dotapp7.dot.state.mn.us/plant/ Accessed 1/19/10.
Noordijk et al.	2009	Biological Conservation	Netherlands	Insects	E	M	Studied effects of different mowing treatments on flower-visiting (pollinating) insects. Recommended a rotational mowing scheme twice per year with hay removal .
Oetting and Cassel	1971	Journal of Wildlife Management	North Dakota	Birds: ducks	E	M	Nest selection and nesting success was higher in unmowed segments of I94 ROW. Recommend no mowing of ditch bottoms or back slopes, minimal mowing of inslopes, and no mowing before July 20 to enhance waterfowl nesting and to reduce maintenance costs of highway right-of-way in duck-producing regions.
Puglisi et al.	1974	Journal of Wildlife Management	Pennsylvania	Deer	E	G	The effect of vegetation on DVCs along I80 in PA was significant only where fencing was absent. Highest DVCs where fence was at edge of wooded area or within 25 yds (23 m) of nearest wooded area. Lowest DVC's where fence was >25 yds of the nearest wooded area. Low DVCs also where fence was in woods.
Rea	2003	Wildlife Biology	British Columbia	Plants	S, E	C	Plants cut in the middle of the growing season produce regrowth that is high in nutritional value for at least two winters following brush-cutting as compared to plants cut at other times of the year, and uncut controls. Recommends cutting brush early in the growing season.
Rea and Gillingham	2001	Journal of Applied Ecology	Canada: British Columbia	Plants	E	C	Willows brushed in early July had shoots that were lower in lignin, higher in digestible protein compared with shoots from earlier brushed or unbrushed willows. Willows brushed after July regenerated negligible shoot material in the 1st year after brushing. Willows brushed in September delayed leaf flush the following spring.
Rea et al.	2007	Environ. Management	British Columbia	Plants	E	C	Timing of brush-cutting influences morphology and phenology of plants for up to 3 years in willow, birch, and twinberry. Recommend roadside vegetation management plans consider cutting time on plant regrowth to reduce attractiveness to herbivores—moose in this case.
Ries et al.	2001	Conservation Biology	Iowa	Insects: Butterflies	E	P	Roadside vegetation management profoundly affected the butterfly community. Species richness of habitat-sensitive butterflies showed a two-fold increase in prairie (native) compared with grassy and weedy (non-natives) roadsides, and abundance increased almost five times more on the prairie than on grassy roadsides.

(continued)

Appendix Table A-1. (Continued)

Author	Year	Journal/ Publication	Location	Species/ Class	Impact[1]	Mgmt[2]	Summary of Results/Recommendations
Roach and Kirkpatrick	1985	TRB	Indiana	Birds & mammals	E, S	P	Evaluated impact of planting shrubs (plots 328' long) on roadside of 4-lane highway. Number of rabbits & birds were significantly higher in shrub (treated) compared to grassy (control) areas. No significant difference in roadkills found in the planted shrub areas compared to grassy areas. Concluded that ROW could be managed to encourage wildlife use without increasing AVCs.
Romin and Bissonette	1996	Great Basin Naturalist	Utah	Deer	E, S	G	DVC model that used highway visibility variable which was insignificant.
Schwabe et al.	2002	National Wildlife Research Center	Ohio	White-tailed deer	$	G	7.7% of DVCs resulted in human injuries and 0.029% resulted in human fatalities in Ohio.
SEMCOG	2007	SE MI Council of Government	Michigan	White-tailed deer	$	G	2.8% of DVCs resulted in human injuries and 0.02% resulted in human fatalities in Michigan.
Sielecki	2004	Ministry of Transportation	British Columbia	Ungulates	$	G	Carcass removal and disposal per collision was estimated at Can$100 in British Columbia.
Tardif Ass.	2003	Tardif Associates	Nova Scotia	Large animals	$	G	90.2% of DVCs resulted in vehicle damage in Nova Scotia. 9.7% of DVCs resulted in human injuries and 0.05% resulted in human fatalities in Nova Scotia.
U.S. Dept. of Labor	2008	U.S. Dept of Labor	United States	N/A	$	G	Provided Consumer Price Index for conversion of past economic estimates to 2007 US$.
U.S. Dept of Transporta-tion	1994	U.S. Dept of Transportation	United States	N/A	$	G	Provided estimates of motor vehicle accident costs.
U.S. Fish and Wildlife Service	1998	U.S. Fish and Wildlife Service	United States	N/A	$	G	Provided 2001estimates of economic values for deer in the United States.
U.S. Fish and Wildlife Service	2003	U.S. Fish and Wildlife Service	United States	N/A	$	G	Provided 2001 estimates of economic values for wildlife-related recreation in the United States.
Varland and Schaefer	1998	ICOWET 1998 Conference	Minnesota	Plants	E	M	Passage of a 1985 law resulted in a sharp decrease (32.5%) in roadside mowing between 1984 and 1986. Peak of mowing activity has remained the same with about 80% occurring between July 1-31.
Voorhees and Cassel	1980	Journal of Wildlife Management	North Dakota	Birds: ducks	E	M	Recommend ditch bottoms, secondary slopes, and back slopes should remain unmowed . For highest waterfowl production vegetation should be kept in an early state of succession by rotational mowing at 3-year intervals; 1/3 of the area each year. Also recommends only one side be mowed at a time to maintain residual cover.

(continued)

Appendix Table A-1. (Continued)

Author	Year	Journal/ Publication	Location	Species/ Class	Impact[1]	Mgmt[2]	Summary of Results/Recommendations
Warner et al.	1992	Wildlife Society Bulletin	Illinois	Birds: Pheasant	E	P M	Provides a cost/benefit analysis based on the increased number of ring-necked pheasants produced on roadside habitat management involving seeding and delayed mowing until Aug 1 each year.
Wilkins and Schmidly	1981	2nd Nat. Symp. Environ Concerns in Right-of-Way Mgmt	Texas	Mammals: Small mammals	E	M	ROW should only be mowed once/yr, preferably after young rodents, rabbits, and ground-nesting birds have left their nests, and after plants have produced seeds—late June in east Texas. Full-width mowing every 3rd or 4th year should be sufficient to prevent woody vegetation from encroaching upon the ROW.

[1]Impact described in article
- **E = Ecological**
- **G = General**
- **S = Safety**
- **$ = Economical**

[2]Management Actions described in article
- **C = cutting**
- **G = general**
- **M = mowing**
- **P = planting**

APPENDIX B – EV0104 TASK 3: CURRENT AND BEST PRACTICES SURVEY

MEMORANDUM

To: Mary Gray, FHWA

From: Gary Alt, Normandeau Associates

Re: **EV0104 Task 3: Current and Best Practices Survey**

Date: October 24, 2011

EXECUTIVE SUMMARY

The vast majority of roadside vegetation best management practices and recommendations address improved safety, promotion of drainage, control of noxious and nuisance weeds, and promotion of desirable natural vegetation. One of the highest priorities for mowing near roadways is to maintain sight distance so motorists can observe and avoid other vehicles, animals or pedestrians, and to be able to read road signs. Best management practices and recommendations specifically addressing deer and other wildlife, based on results from this survey, are comparatively rare and largely limited to two categories: (1) restricting the timing of mowing to protect ground nesting birds, and (2) selection of plants to revegetate roadsides that are less likely to attract large animals which may cause potential safety hazards to motorists.

A reduction in roadside vegetation mowing has occurred throughout a majority of the United States in recent years based on results from this survey. Twenty-one of 24 states (88%) that responded to the survey reported a reduction in their mowing programs. For those 21 states that reduced mowing, 17 did so statewide while 4 reduced mowing in only some parts of their state. The timing of when roadside mowing programs were reduced varied from 1968 to 2010; however, nearly two-thirds (13/21=62%) of the states that had reduced mowing programs made their reductions in the past three years (2008-2010); 81% (17/21) in the past 7 years (2004-2010). Economic concern was the overwhelming reason provided why roadside mowing programs have been reduced in surveyed states with ecological concern being secondary. Ecological concerns included impacts of survival of ground nesting birds, establishment of native plants, and weed control. The nine pooled fund member states appear to be comparable to the rest of the country with regard to reduced mowing policies.

A comparison of “reduced” and “typical” mowing policies for each of the 21 surveyed states that reported a reduced mowing policy involved a combination of changes in the number of mowing cycles per year, seasonal timing of mowing, areas mowed, and/or mowing height. A reduction in the number of mowing cycles and/or areas mowed was reported for all 21 of the surveyed states with “reduced” mowing policies. However, a reduction in mowing height and/or changes in the timing of mowing was less common, involving only 8 of those 21 states. Washington reported that a higher mowing height was advantageous to plant stability and sustainability.

Mowing regimes are typically not the same throughout all areas within most states for a variety of reasons. Mowing requirements are impacted by differences in temperature and rainfall due to changes in latitude, topography, and/or elevation which in turn impacts grass species composition, length and timing of growing seasons, and growth patterns. Different classifications of roads, the location within the Right of Way (ROW) and the purpose of mowing (or not mowing) also impact mowing regimes within a state. Interstate (multi-lane) highways tend to have more mowing cycles than secondary roads. For safety reasons, locations nearest the roadway that may impact sight distance tend to be mowed more frequently than areas beyond the recovery zone. As a rule, there tends to be more mowing cycles, lower mowing heights, and more of the ROW areas mowed in urban areas and other high human use areas, such as rest areas and visitor centers, than in rural areas. Other factors that contribute to a variety of mowing regimes being used within a state are the concern of mortality of ground nesting birds during the nesting season, control of weeds (mowing prior to seed production of weed species), establishment and maintenance of more desirable native vegetation, drought conditions, and fire safety.

Fifteen states indicated that neither a perceived or demonstrated reduction in DVC played a role in current roadside vegetation management policies while 9 states reported a perceived reduction. <u>**We found no evidence from the survey that a demonstrated (quantified) reduction of DVC rates had been documented in any state due to changes in roadside vegetation management policies.**</u>

INTRODUCTION

The primary objectives of this task were to:

1) document the "typical" roadside vegetation management policies and "best" management practices currently applied in the United States, and
2) to determine if policies used by pooled fund member states are typical of those used throughout the country.

To meet these objectives, the research team conducted a survey to gather information on roadside vegetation management policies currently in place in each of the nine pooled fund member states and a sample of 15 non-member states throughout the country (Figure 1).

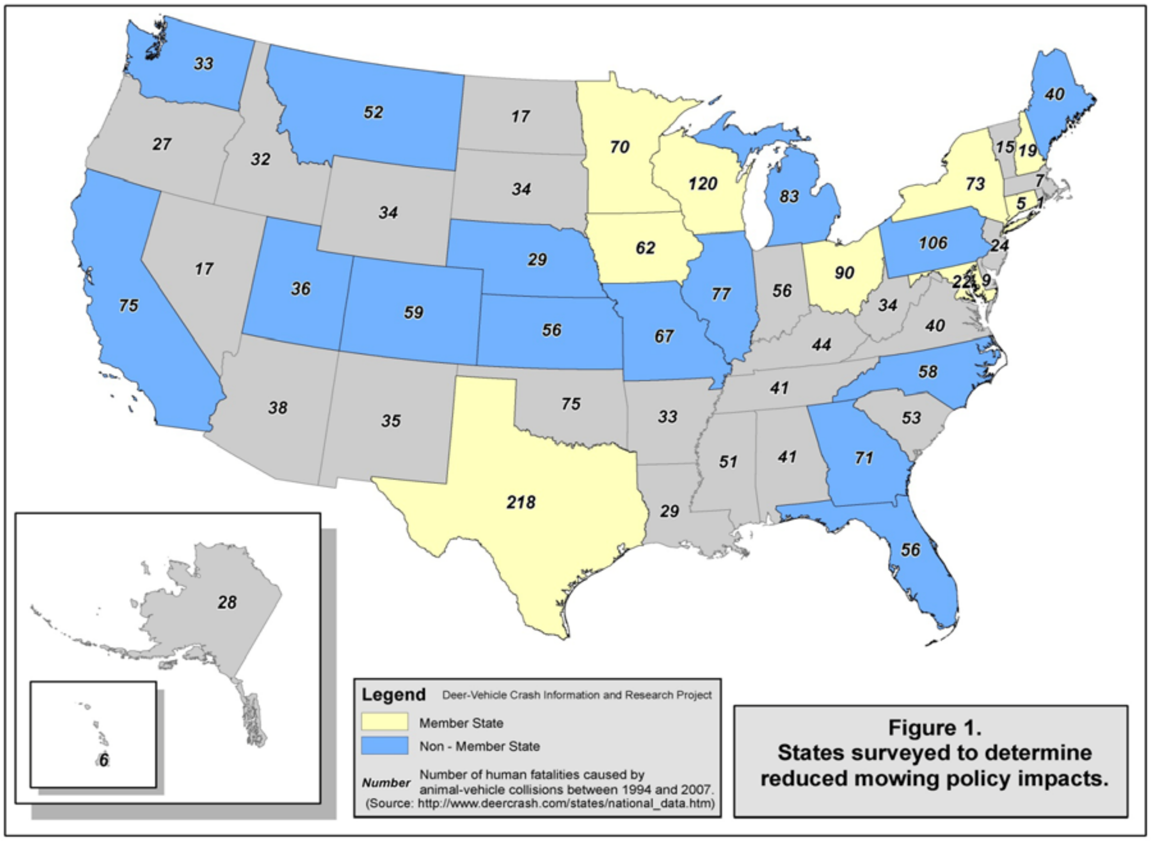

Figure 1. States surveyed to determine reduced mowing policy impacts.

METHODS

The information on current mowing policies and practices were collected from 24 Departments of Transportation (DOT) using an e-mail-questionnaire designed using SurveyMonkey.com software (Appendix A), follow-up phone interviews with the selected states, and an examination of roadside vegetation management handbooks and/or written protocols for states where this information was available. The survey questions were designed to determine where, when, and why reduced roadside mowing policies were implemented throughout the country as well as to define differences between "typical" compared to "reduced" roadside mowing policies for states that had reduced mowing programs. The survey also collected information to determine the timing and frequency of mowing, mowing height, how (and why) regimes differed across the state, and to determine if a desire to reduce DVC's (deer-vehicle collisions) influenced mowing regimes and other roadside vegetation management decisions, including plantings and clearing of forested cover types adjacent to roadways (Appendix A). Phone interviews consisted of a set of standard questions followed by a free-ranging discussion. Challenges to changing or implementing new roadside vegetation management policies were also identified through the survey process. A special focus was placed upon determining if current practices were implemented due to a perceived, as compared to a demonstrated (quantified), impact on the rate of DVC.

RESULSTS AND DISCUSSION

Best Management Practices/Recommendations

The vast majority of roadside vegetation best management practices and recommendations address:

- improved safety,
- promotion of drainage,
- control of noxious and nuisance weeds, and
- promotion of desirable natural vegetation.

One of the highest priorities for mowing near roadways, for example, is to maintain sight distance so motorists can observe and avoid other vehicles, animals or pedestrians, and to be able to read road signs. Trees are removed from near roadways to prevent them from growing large enough to become a hazard to vehicles that leave the road. Best management practices and recommendations specifically addressing deer and other wildlife, based on results from this survey, are comparatively rare and largely limited to two categories: (1) restricting the timing of mowing to protect ground nesting birds, and (2) selection of plants to revegetate roadsides that are less likely to attract large animals which may cause potential safety hazards to motorists.

Restricting the timing of mowing to protect ground nesting birds was a best management practice in a number of states. Legislation in Iowa and Michigan delayed mowing until after July 15th on many of the areas to be mowed in an effort to improve nesting success for ring-necked pheasants and other ground nesting birds. Wisconsin only permitted mowing in the clear zone beyond the shoulder cut after July 4th due to concern for ground nesting birds. The timing of nesting for ground nesting birds can vary due to environmental and climactic conditions and it would be recommended to coordinate the establishment of delayed mowing programs with the state's wildlife agency to ensure proper timing.

The selection of plants for revegetating roadsides that do not attract deer or other large herbivores was the topic of discussion for a number of states during the survey process. However, surprisingly Minnesota was the only state of 24 surveyed that indicated that they actually had a list of recommended plants for roadside revegetation that are less likely to attract deer or other large herbivores. Georgia indicated that they discouraged the planting of certain oaks that have acorns that are especially attractive to deer. New York and Washington indicated that they avoid planting clover along roadsides because of its known attraction to deer. Texas indicated that it was looking for alternative cool season temporary covers to replace wheat and oats.

Best management practices for roadside vegetation management as it relates to DVC appear to be more conjectural than documented based on results from this survey. Strong opinions were expressed by DOT personnel during this survey supporting all three possible outcomes (increasing, decreasing, or no effect) with regard to potential impacts of reduced mowing on the number of DVC; however, supporting data was lacking. We found no evidence from this survey that a demonstrated (quantified) reduction of DVC rates had been documented in any state due to changes in roadside vegetation management policies, including reduced roadside mowing. That does not mean a relationship does not exist, of course, but there is clearly a need for further study to document what relationships do exist between vegetation management policies and rates of DVC.

Where, When, and Why Roadside Mowing Was Reduced in the United States

A reduction in roadside vegetation mowing has occurred throughout a majority of the United States in recent years based on results from this survey. Twenty-one of 24 states (88%) that responded to the survey reported a reduction in their mowing programs (Table 1). Only California, Florida, and North Carolina reported no reduction in mowing. For those 21 states that reduced mowing, 17 did so statewide while 4 reduced mowing in only some parts of their state (Table 1). The timing of when roadside mowing programs were reduced varied from 1968 to 2010; however, nearly two-thirds (13/21=62%) of the states that had reduced mowing programs made their reductions in the past three years (2008-2010); 81% (17/21) in the past 7 years (2004-2010).

All 21 of the states, with reduced mowing programs, indicated economic concern was a factor in the decision to reduce mowing. Economic concern was the overwhelming reason provided why roadside mowing programs have been reduced with ecological concern being secondary (Table 1). Thirteen states (62%) indicated an ecological concern was also a factor considered in reduced mowing programs. However, ecological concern was never listed by itself; rather it was always listed in association with economic concern. The most common ecological concerns were:

- impacts on survival of ground nesting birds,
- establishment of native plants, and
- weed control.

In Maine, for example, the reduction was brought on by a governor's executive order to reduce reliance on fossil fuels. Safety of a reduced mowing program was listed as a concern in 4 states (20%) in reference to an anticipated reduction of exposure (danger) of DOT employees to the traffic as a result of reduced time mowing along roadways (positive concern), and/or a concern that reduced mowing would adequately maintain safety sight distance and clear zones (negative concern).

Table 1. Where, When, and Why Roadside Mowing Was Reduced in 24 Surveyed States.

STATE	REDUCED MOWING POLICY			CONCERNS AND LEGISLATION THAT LED TO REDUCED MOWING			
	Yes/No	Year Implemented	All/Part of State	Safety	Economic	Ecological	Legislation
California	No		None				
Colorado	Yes	2000	Part		X	X	
Connecticut[1]	Yes	2009	All		X		
Florida	No		None				
Georgia	Yes	2009	Part		X		
Illinois	Yes	2005	All		X		
Iowa	Yes	1970's & 2010	All		X	X	X
Kansas	Yes	2009	All		X	X	
Maine	Yes	2006	All		X	X	
Maryland	Yes	2009	All		X		
Michigan	Yes	2008	All		X		X
Minnesota	Yes	1989	All		X	X	
Missouri	Yes	1980's & 2005-2009	Part		X	X	
Montana	Yes	2006	All	X	X	X	
Nebraska	Yes	1968	All		X	X	
New Hampshire	Yes	2004	Part		X		
New York	Yes	2008	All	X	X	X	
North Carolina	No		None				
Ohio	Yes	2010	All	X	X	X	
Pennsylvania	Yes	2008	All		X	X	
Texas	Yes	2010	All		X		
Utah	Yes	2008	All		X	X	
Washington	Yes	2001	All	X	X	X	
Wisconsin	Yes	2009	All		X		

[1]Pooled fund member states are highlighted in yellow.

Iowa and Michigan reductions in roadside mowing programs were created by legislation. In both cases this legislation delayed mowing until after July 15th on many of the areas to be mowed in an effort to improve nesting success for ring-necked pheasants and other ground nesting birds.

The nine pooled fund member states appear to be comparable to the rest of the country (or at least the 15 surveyed non-fund states) with regard to reduced mowing policies. A vast majority of both member (9/9=100%) and non-member (12/15=80%) states reported having reduced mowing policies which were largely implemented in the past 7 years. All member (9/9=100%) and non-member (15/15=100%) states indicated economic concerns led to reduced mowing policies; roughly half of member (4/9=44%) and non-member (8/15=53%) states expressed ecological concerns, and a minority of both member (2/9=22%) and non-member (2/15=13%) states indicated that safety concerns led to reduced mowing policies. Of the two surveyed states where legislation created reductions in roadside mowing programs, one (Iowa) was a member and one (Michigan) was a non-member.

Comparison of "Typical" and "Reduced" Mowing Policies

A comparison of "reduced" and "typical" mowing policies for each of the 21 surveyed states reported:

- a reduced mowing policy involved a combination of changes in the number of mowing cycles per year,
- seasonal timing of mowing,
- areas mowed, and/or
- mowing height (Table 2).

A reduction in the number of mowing cycles and/or areas mowed was reported for all 21 of the surveyed states with "reduced" mowing policies. However, a reduction in mowing height and/or changes in the timing of mowing was less common, involving only 8 of those 21 states (Table 2).

Two-thirds (14/21=67%) of the surveyed states with "reduced" mowing policies indicated a reduction in the number of mowing cycles per year; most commonly (8 of14=57%) they reduced the number of mowing cycles by just one cycle. Of the 21 responding states with reduced mowing policies, the largest reduction in the number of mowing cycles per year was reported for Maryland and Michigan (Table 2). In Maryland the "typical" number of mowing cycles was reported as 4-6 full cutbacks, but the "reduced" policy involved only 2 full cutbacks and 3-4 one pass cuts. In Michigan, the number of mowing cycles was reduced from 3+ cycles to primarily a single cycle that occurs between June 1 and July 4th. Due to the magnitude of reduced mowing in Maryland and Michigan, they are states of interest for further study to evaluate the impacts of reduced mowing policies on the rate of DVC.

More than half of the states from the survey that reported a reduced mowing policy (11/21=52%) indicated that they had reduced the areas mowed. In a number of states "typical" mowing policy was to mow ROW to ROW (full cuts) multiple times per year but "reduced" policies restricted mowing to areas closer to the pavement or at least reduced the frequency that the areas were

Table 2. Comparison of "Typical" and "Reduced" Mowing Policies for 21 States with Reduced Mowing Policies.

State	#of Mowing Cycles		Timing of Mowing		Areas Mowed		Mowing Height (In)	
	Typical	Reduced	Typical	Reduced	Typical	Reduced	Typical	Reduced
CO	2[1]	1	Spring & Fall	Late Spring or Fall	15 ft from pavement edge	15 ft from pavement edge	6-8	6-8
CT	2-3	2	No Dates Required	No Dates Required	All ramp & bowl areas	Ramp & bowl areas to 16 ft from pavement edge	3	3
GA	3[3]	2[3]	May 1-Sep 15	May 1-Sep 15	Same as reduced	Same as typical	6	6
IL	3+	2	1st by July 1 2nd as needed 3rd as needed	1st by Memorial Day 2nd after Labor day	Same as reduced	Same as typical	6	6
IA	3[4]	<3[4]	Spring through Fall	After July 15th	ROW to ROW	Only areas needing weed or brush control or sight distance	3-4	6
KS	?	?	April 15-July 15	April 15-Oct 1	Shoulder and Sight Triangles	Shoulder and Sight Triangles	6	6
ME	1[5]	0-1[5]	Mid May-Mid Nov	Mid May-Mid Nov	Same as reduced	Same as typical	4	4
MD	4-6[6]	2[6]	May through Oct	May through Oct	Mowable medians & roadsides-full cuts	Mowable medians & roadsides (only 1 pass for 3-4 cuts + 2 full cuts)	3.5-4.5	3.5-4.5
MI	3-5	1	May, July, Sep	June	12 ft adjacent to shoulder and wider at clear vision areas	12 ft adjacent to shoulder and wider at clear vision areas	5	5
MN	2+	1-2	May to Oct	After Aug 1 except for top cut & weeds	Entire ROW each year	Entire ROW once every 5 years	4-6	4-6
MO	7	7	7	7	Greater acreage	Reduced acreage	7	7
MT	1-3	1-3	May and June	July[8]	Beyond 15 ft from edge of pavement	Concentrated mostly within 15' from edge of pavement	<6	6-8
NE	2-3	2-3	May-Oct	May-Oct	ROW to ROW	15' from edge of pavement	5	5

Table 2. Continued.

State	#of Mowing Cycles		Timing of Mowing		Areas Mowed		Mowing Height (In)	
	Typical	Reduced	Typical	Reduced	Typical	Reduced	Typical	Reduced
NH	1[9]	0[9]	May 1-Oct 1	May 1-Oct 1	To tree line 1 year, to ditch line 2nd yr	Mostly just intersections	4-6	4-6
NY	2-3	2-3	May-Dec	May-Dec	ROW to ROW	15 ft from pavement for first 2 mowings, 3 pass on final mowing to control woody veg.	4	4
OH	4	3	May-Oct	May-Oct	Recovery zone (30 ft from white line) 3 times/yr, full cut for final mowing	Recovery zone (30 ft from white line) 2 times/yr, full cut for final mowing	6-8	6-8
PA	3-4	3-4	May 15-Sep 15	May 15-Sep 15	Full width to slope or ROW 3-4/yr	Full width to slope or ROW 1/yr, 2-3 limited mowings (10 ft wide on right side and 5 ft wide everywhere else).	3-5	4-8
TX	3-4	2-3	All 12 months	All 12 months	Same as reduced	Same as typical	5-7	5-7
UT	1	1	July-Sep	July-Sep	ROW to ROW 1/yr	1 pass (6-8 ft) 1/yr, ROW to ROW 1/3-5 yr	6	6
WA	Up to 4	<4	April-Sep	April-Sep	ROW to ROW	1 pass	2-6	6-8
WI	2-3	1	June-July 4	June-July 4	1 pass	1 pass	> 6	> 6

[1]Lightly shaded (gray) cells indicate categories where typical and reduced mowing policies are different for that state.
[2]Pooled fund member states are highlighted in yellow.
[3]Reduction in number of mowing cycles in Georgia pertained only to interstate highways.
[4]Reduction in number of mowing cycles in Iowa went from 3 (typical) to "only as needed for safety or operational purposes".
[5]Reduction in number of mowing cycles applies only to rural roads in Maine.
[6]"Typical" number of mowing cycles in MD was 4-6 full cutbacks, "reduced" policy involved only 2 full cutbacks and 3-4 one pass cuts.
[7]Was unable to get specific data for Missouri.
[8]Reduced mowing policy in MT delays mowing until after July 1 to let desirable species mature (reproduce).
[9]In NH all roads typically mowed once but, depending on budgets, recently some years mowing is restricted to intersections & sightline issue areas.

mowed which were a greater distance from the traffic (Table 2). For example, Minnesota's "typical" policy was reported to mow ROW to ROW annually, but its current "reduced" policy only calls for full width mowing once every five years. Utah's "typical" mowing policy was reported to mow ROW to ROW once per year and its current "reduced" policy is to mow a single pass (6-8 feet) nearest the pavement once per year and a full cut (ROW to ROW) once every three to five years. Pennsylvania reported full width mowing to the slope or ROW 3-4 times per year in its "typical" policy, but full width to slope or ROW once per year and 2-3 limited mowings (10 feet wide on right side and 5 foot wide everywhere else) in its "reduced" policy. Iowa reported reducing its mowed areas from ROW to ROW to only areas needing weed or brush control or areas requiring maintenance of sight distance improvement.

Six states reported a change in the seasonal timing of mowing between their "typical" and "reduced" mowing polices; Illinois, Iowa, Kansas, Michigan, Minnesota, and Montana (Table 2). Iowa formerly mowed from spring through fall but now restricts its mowing until after July 15th. Michigan formerly mowed from May through September but now restricts most of its mowing to June. Minnesota formerly mowed between May and October but now restricts most of its mowing until after August 1st. Montana used to mow primarily in May and June but now restricts most of its mowing to July. Illinois typically completed three major mowing cycles, the first by July 1st, and the second and third as needed. Now in Illinois the first mowing cycle is to be completed by Memorial Day and the second after Labor Day. In Michigan and Iowa the timing of mowing was changed as a result of legislation with a goal of improving nesting success for ring-necked pheasants and other ground-nesting birds.

Mowing height appears to be less impacted by implementation of "reduced" mowing policies than other mowing factors. Only four of the 20 surveyed states (Iowa, Montana, Pennsylvania, and Washington) that reported having a "reduced" mowing policy made changes to mowing height. In each of those four states mowing height was increased by several inches. Washington reported that a higher mowing height was advantageous to plant stability and sustainability.

With regard to "typical" and "reduced" mowing policies, pooled fund member states appear to be comparable to the rest of the country. All of the pooled fund states (9/9=100%) and all of the non-fund states with reduced mowing policies (12/12=100%) reduced either the number of mowing cycles and/or the areas mowed. Only half or less of the pooled fund states (2/9=22%) and non-fund states with reduced mowing policies (6/12=50%) reduced mowing height and/or timing of mowings.

How and Why Timing, Frequency and Height of Mowing Differ Within States

Mowing regimes are typically not the same throughout all areas within most states for a variety of reasons. Mowing requirements are impacted by differences in temperature and rainfall due to changes in latitude (as you go north colder temperatures and shorter growing seasons), topography and/or elevation which in turn impacts grass species composition, length and timing of growing seasons, and growth patterns. For example, in North Carolina the coastal plain region is dominated with warm-season grass species (centipede, Bermuda, and bahia) and has a growing season more than a month longer than in the mountains of western North Carolina which is dominated by cool-season grasses (tall fescue, bluegrass, and hard fescue). Similarly, growing seasons in New York are shorter in the Adirondack and Catskill Mountains as compared to lower elevations within that state. Growing seasons are about six weeks longer, requiring additional mowing cycles, in the lower elevations of southeastern Pennsylvania compared to the higher elevations of the northcentral and northeastern regions of the state. Due to the shorter growing season and lower growth rates in northern Maine only one mowing cycle is required while two or three mowing cycles are required in southern Maine. In Colorado, where elevations vary from 3,000 to 14,000 feet, climate and growing seasons vary greatly which necessitates different mowing regimes within the state. Nebraska provides an example of precipitation impacting mowing regimes where more mowing cycles are required in the eastern portion of the state due to greater rainfall than the western portion which is dryer.

Different classifications of roads, the location within the Right of Way (ROW) and the purpose of mowing (or not mowing) also impact mowing regimes within a state. Interstate (multi-lane) highways tend to have more mowing cycles than secondary roads (Table 3). For safety reasons, locations nearest the roadway that may impact sight distance tend to be mowed more frequently than areas beyond the recovery zone. As a rule, there tends to be more mowing cycles, lower mowing heights, and more of the ROW areas mowed in urban areas and other high human use areas, such as rest areas and visitor centers, than in rural areas (Table 3).

Other factors that contribute to a variety of mowing regimes being used within a state are:

- the concern of mortality of ground nesting birds during the nesting season,
- control of weeds (mowing prior to seed production of weed species),
- establishment and maintenance of more desirable native vegetation,
- drought conditions, and
- fire safety.

Iowa, Minnesota, Nebraska, New York, and Utah all mentioned timing of mowing being impacted by concern for survival of ground nesting birds. Iowa and Utah mentioned the need for modified mowing regimes to allow native species to get established or to control weeds. In dry areas of the western United States mowing regimes are sometimes modified within states to reduce fuel for potential fires to start along roadways.

According to survey responses, it is the exception and not the rule that mowing regimes are the same throughout the entire state. Only four of the 24 states (17%) indicated that their roadside vegetation mowing policies recommended the same number of mowing cycles per year, statewide. Michigan, Wisconsin and Utah recommended a single mowing per year, while Maryland does two full cutbacks annually.

Nine of the 24 states (37%) indicated that their roadside vegetation mowing policies recommended the same dates of mowing statewide. Illinois, Iowa, Kansas, Michigan, Minnesota, Montana, Nebraska, Ohio, and Wisconsin were the nine states with the same mowing dates for all regions within their states.

In contrast to mowing frequency or dates of mowing, recommended mowing height policies were the same, statewide, in over three-quarters of the surveyed states (20/24=83%). The

Table 3. Number of Mowing Cycles, Mowing Dates, and Mowing Heights for 24 Surveyed States.

State	Mowing Same Statewide?[1]			Number of Mowings	Mowing Dates	Mowing Height	Comments
	Number	Dates	Height				
CA	No	No	No	1-3	Mar-Sep	6-12	#: variable based on eco province, vegetation type, location, funding, equipment, history, etc. Dates: Varies with Eco Provinces and rainfall.
CO	No	No	Yes	Variable	May-Oct	6-8	#: variable based on wide variety of terrain and climate. Dates: Vary with elevations which range 3,000-14,000'.
CT[2]	No	No	Yes	2-3 secondary, variable on multi-lane rds.	Variable	3	#: 2-3 on secondary roads but variable on multi-lane roads- whenever grass reaches 8". Dates: Whenever grass reaches 8"
FL	No	No	Yes	Variable	Variable	5-18	#: determined by when grass reaches mowing height.
GA	No	No	Yes	3 on Interstate, 2 on other rds.	May-Sep	6	Dates: First mowing cycle typically begins between May 1-15. Final mowing cycle begins Sep 1-15.
IL	No	Yes	Yes	Variable	Late Spring-Late Fall	6	#: of mowing variable based on local conditions. Date: Growing season longer in southern IL.
IA	No	Yes	Yes	Variable	After July 15th	6	#: based on when grass gets to mowing height and mowing purpose. Dates: Most mowing delayed until after July 15 to improve nesting success of ring-necked pheasants and other ground nesting birds.
KS	No	Yes	Yes	1	April 15-Winter	6-8	#: Entire ROW mowed once every 4 years. Shoulder and sight distance mowing as needed. Dates: Shoulder mowing April 15 to Oct 1. Mow out of ROW after Oct 1. Height: 6"for shoulder and sight distance, 8" mow out of ROW.
ME	No	No	Yes	2-3 in S Maine, 1 in N Maine	May-Nov	2.5-4	#: Mowing more cycles in southern Maine because growing season is longer and rate of growth is higher. Height: 4" for Interstate inslopes and backslopes, 2.5" for urban interchanges.
MD	Yes	No	Yes	2	Variable	2.5-4.5	#: 2 full cutbacks plus 3-4 one-pass cuts. Dates: Vary with elevation-longer growing season near coast. Height: Tractor mowing is 3.5-4.5", hand mowing is 2.5-3.5".
MI	Yes	Yes	Yes	1	June 1-July 4	5	
MN	No	Yes	Yes	Variable	May-Oct	4-6	#: Based on vegetation growth rate, rural or urban, and location in ROW.

Table 3. Continued.

State	Mowing Same Statewide?[1] Number	Dates	Height	Number of Mowings	Mowing Dates	Mowing Height	Comments
MO	No	No	No	Variable	Pre-Memorial Day-Post Labor Day	4-6	#: Urban areas mowed more frequently than rural areas.
MT	No	Yes	Yes	Variable	July-Fall	6-8	#: Growth conditions vary widely in MT. Dates: Mowing delayed until after July 1 to let desirable species time to mature and reproduce.
NE	No	Yes	Yes	1-2 in W NE, up to 3 in E.	May-Oct	5	#: Less rainfall, shorter growing season, different species in Western NE requires less mowing cycles. Dates: Mowing delayed until after July 1 in Western NE.
NH	No	No	Yes	1	May-Oct	4-6	#: Budget driven: Low budget years only sightline issues areas mowed, all roads mowed once during adequate budget years.
NY	No	No	Yes	3 on Interstates, 2 on other rds.	Apr-Dec	4	Dates: Variable geographically due to climate. Mowing delayed in some areas until July or Aug to accommodate ground nesting bird species.
NC	No	No	Yes	Variable	June-Fall	4	#: Variable due to diversity of topography & climate.
OH	No	Yes	No	3	Pre-Memorial Day toPost Labor Day	6-8	#: Typically 3 but more in some areas due to public expectations. Height: Typically the mowing height is 6 to 8" but the grass may be mowed shorter in urban areas.
PA	No	No	Yes	3-4	Mar-Nov	4-8	#: 3 in most areas, 4 in urban and warmer areas.
TX	No	No	No	2 rural, 3 urban	Jan-Dec	5-7	Dates: Mowing can occur during any month due to variations in climatic conditions in TX. Height: 7" rural, 5" urban.
UT	Yes	No	Yes	1	Variable	6	Dates: Variable due to variation in climates in UT.
WA	No	No	Yes	Variable	May-Sep	6-8	#: West of Cascades requires mowing, east does not.
WI	Yes	Yes	Yes	1	May-July 4	6	#: Additional mowing is done for safety reasons. Dates: Start mowing when grass reaches 12" but most mowing must stop by July 4.

[1]Answers based on the following 3 questions:

1. Is the recommended number of times you mow per year the same throughout your state?
2. Are the recommended dates of mowing the same throughout your state?
3. Is the recommended height of mowing the same throughout your state?

[2]Pooled fund member states are highlighted in yellow.

exceptions were California, Missouri, Ohio, and Texas. In California recommended mowing heights ranged from six to 12 inches, depending on terrain and the vegetation being mowed. In Missouri, minimum mowing height was six inches for most areas but areas with walk behinds had a minimum mowing height of four inches. In Ohio, the typical mowing height is six to eight inches but may be mowed shorter in urban areas. Similarly, in Texas mowing height is seven inches for rural areas and five inches for urban areas.

Challenges to Changing or Implementing New Policies

In an effort to determine challenges and recommendations to changing or implementing new roadside vegetation management polices based on experience, the following question was asked on the survey to 24 different state DOTs:
"What challenges have you experienced in attempting to change or implement new roadside vegetation management policies in your state and what recommendations do you have on how other states might make such changes?" Below is a list of responses:

1. Public complains about appearance of roadsides due to reduced mowing, use of herbicides, and removal of roadside trees. They do not appear to understand that these policies were important to public safety and reduced labor costs to control vegetation. Public education is recommended.

2. Severe budget restrictions and controlled funding has not allowed much flexibility for fund managers at the Shop level. Establishing policy changes early, wide distribution of policy and senior management driven support is crucial.

3. State legislation dictates when vegetation can be cut beyond the routine 12-foot mow line adjacent to the shoulder on all roads. This limits our ability to effectively manage roadside vegetation, especially woody species.

4. Join the NCHRP ADH-50 Roadside Vegetation Managers Committee.

5. Challenges include lots of opinions with differing desired outcomes; habitat for ground nesting birds vs. neat, tidy look for example. Difficult to get buy in both internally and externally. Lack of understanding of what is involved (number of acres, type of terrain, number of neighbors, vegetation types, state and federal laws, etc. Common misperception is that if you mow more, motorists will see the deer and avoid hitting them. Recommendations include assembling a team (with varied backgrounds) to develop policy and guidelines. Clearly define and communicate expectations. Obtain support from the top down with appropriate people held accountable. Develop and implement communications plan. Measure results, including a breakdown by district for comparison.

6. As a scenic state, many residents do not want trees cut regardless if there are demonstrated safety advantages. Removal of trees also reduces the need for salt application, and therefore less likely to attract the animals that may want the salt.

7. We greatly reduced the type and amount of herbicides we use on our right-of way. The plan was rolled out in the early spring. I would recommend that if a state wanted to revamp their program they should do so in the early winter.

8. Need to change the motorist's expectations and create a new paradigm. Roadside turf does not need to look like a golf course or a residential lawn. Need to weather the storm of consumer expectation change before policy changes are accepted.

9. Crews like to mow. They say it reduces DVC, and prevents fires. No data to prove either.

10. Development of area IVM plans and the annual evaluation and update process that goes into maintaining the plans has been a tremendous help in organizing and planning for our agency's response to this issue. In many cases of DVCs there is no real solution in relation to vegetation management, but where there are known high frequency DVC or AVC locations there are ways to mitigate through vegetation management practices without trying to implement across the board policy.

DVC Influence on Roadside Vegetation Policies

To determine the influence that DVC considerations may have had on roadside vegetation management policies, the following two-part question was asked in the email questionnaire to 24 state DOTs:

"Has a desire to reduce deer-vehicle collisions (DVC) or large animal-vehicle collisions (AVC) influenced mowing policies or any other roadside vegetation management policies, including plantings and/or clearing of forested cover types adjacent to roadways? If yes, please briefly explain which policies and how they were considered."

Fifteen of 24 (63%) states indicated that DVC considerations did not influence roadside vegetation management policies and 9 (37%) states indicated that DVC considerations did influence roadside vegetation management policies. Six states (CT, ME, MT, NH, PA, and WA) indicated that they had policies to clear woody vegetation from highways in an effort to reduce DVC or AVC.

Three states (NY, OH, and WA) commented on DVC considerations on mowing policies. Ohio stated that they like to keep the recovery areas mowed so the motorist can see deer soon enough to react. Washington stated that areas with known DVC are mowed out wider, and New York stated that there was no systematic evidence to date of a relationship of mowing to DVC/AVC.

Five states (GE, MT, NY, TX, and WA) commented on DVC considerations on planting policies. Georgia discouraged the planting of certain oaks that have acorns that are especially attractive to deer. Montana plants lower growing grasses that are undesirable forage to prevent attracting deer and to improve sight distance. New York attempts to plant only vegetation that does not attract deer and no longer plants clover for that reason, and Washington also avoids planting clover as a ground cover because of its grazing attraction. Texas indicated it is looking for alternative cool season temporary covers to replace wheat and oats.

To determine if current roadside vegetation management practices were implemented due to a perceived, as compared to a demonstrated (quantified) impact on the rate of DVC, we asked the following multiple choice question on the survey,
"Which of the following statements best describe the role of deer-vehicle collision (DVC) rates in current roadside vegetation management policies in your state: 'At least some of our roadside vegetation management policies were created in response to:

A) a perceived reduction of DVC rates;
B) a demonstrated (quantified) reduction of DVC rates;
C) both a perceived and a demonstrated reduction of DVC rates; or
D) None of the above.'"

Fifteen states indicated that neither a perceived or demonstrated reduction in DVC played a role in current roadside vegetation management policies while 9 states reported a perceived reduction. **We found no evidence from the survey that a demonstrated (quantified) reduction of DVC rates had been documented in any state due to changes in roadside vegetation management policies.**

APPENDIX A

DVC - Reduced Mowing Survey

Introduction

The Federal Highway Administration (FHWA) and the Deer-Vehicle Crash Information and Research Center (DVCIR) have funded and coordinated this survey as part of a larger project to study current roadside vegetation management policies and their possible relationships to deer-vehicle collisions or large animal-vehicle collisions.

The purpose of this survey is to document the "typical" roadside vegetation management policies as currently applied in the United States. In recent years, a number of states have reportedly reduced roadside mowing in response to a variety of suggested ecological or economic factors. Of particular interest in this survey will be to define and document "typical" compared to "reduced" mowing policies for states that have implemented reduced mowing policies and determine if there are any corresponding effects on deer- or large animal-vehicle collisions.

Results from this survey, combined with results from other parts of this project, will be used to produce a report for inclusion in FHWA best practices manual for reduction of animal-vehicle collisions.

We would very much appreciate it if you would complete this survey which should take about 30 minutes. Your input, as the people who implement the policies, is very important. Your participation will make an important contribution to our understanding of the current status of roadside vegetation management in the country and its possible implications to animal-vehicle collisions.

Please return your survey by December 27th. If you have questions or a need for more information please feel free to call me at 415-488-4186 (8am-5pm Pacific Time) or email at (galt@normandeau.com). Thank you. Gary Alt, Normandeau Associates

Survey Questions

Which state in the United States are you reporting information for in this roadside vegetation management survey?

Please supply contact information for the respondent.

Name:

Job Title:

Employer:

Email address:

Phone number:

1. Does your state have a handbook and/or written policies with recommended protocols for roadside vegetation management?

- ◯ Yes
- ◯ No

If yes, could you please provide an electronic copy or an internet access address so that we may review them?

Address:

Handbook:

Written Policies:

Additional Comments:

If no, please briefly explain how do you decide when, where and how often to mow?

2. According to your roadside vegetation mowing policies, is the recommended number of times you mow per year the same throughout your state?

- ○ Yes
- ○ No

If yes, how many times per year do you typically mow?

If no, please briefly explain how, where, and why the number of times you mow differs for different areas within your state:

3. According to your roadside vegetation mowing policies, are the recommended dates of mowing the same throughout your state?

- ○ Yes
- ○ No

If yes, what are the statewide dates for beginning and ending mowing?

Beginning:

Ending:

Additional Comments:

If no, please briefly explain where and why beginning and ending dates for mowing differ for different areas:

Beginning:

Ending:

Additional Comments:

DVC - Reduced Mowing Survey

4. According to your mowing policies, is the recommended height of mowing the same throughout your state?

- ○ Yes
- ○ No

If yes, what height of mowing is recommended statewide?

If no, please briefly explain how, where, and why the mowing heights are chosen for different areas in your state:

5. Recently there has been a national trend in reduced roadside mowing (i.e. less area mowed and/or fewer mowings per year). Has your state implemented a "reduced" mowing policy?

- ○ Yes
- ○ No

Survey Questions (Cont.)

6. Is the reduced roadside mowing policy for all or just some portions of your state?

- ○ All
- ○ Some Portions

7. In what year was this reduced mowing policy implemented in your state?

8. Please describe in the textboxes provided below the differences between "typical" compared to "reduced" roadside mowing policies in your state.

"Typical" Number of Mowings/Year

"Typical" Timing of Mowing (Dates)

"Typical" Areas Mowed

"Typical" Mowing Height

Additional Comments

"Reduced" Number of Mowings/Year

"Reduced" Timing of Mowing (Dates)

"Reduced" Areas Mowed

"Reduced" Mowing Height

Additional Comments

9. The reduced mowing policy change in your state was implemented in response to which of the following concerns:
(Tick all that apply and please briefly explain below.)

- [ ] A) safety
- [ ] B) economic
- [ ] C) ecological
- [ ] D) other factors

If safety was a concern, what type of safety concern was being addressed?

If the economic factor was a concern, are cost savings data or estimates of savings available?

Could you share the cost savings data with us?

If the ecological factor was a concern: Please explain the nature of the concern (i.e. deer-vehicle collisions, increased protection of nesting birds, habitat improvement, weed control, etc.):

Additional comments:

10. Has there been any data collected or analyzed to evaluate the safety, economic, or ecological impacts of "reduced" compared to "typical" mowing practices in your state?

- ○ Yes
- ○ No

If yes, please briefly explain. If at all possible, please provide an electronic copy or an internet access address so that we may review any available documents summarizing the results.

Survey Questions (Cont.)

11. Has a desire to reduce deer-vehicle collisions (DVC) or large animal-vehicle collisions (AVC) influenced mowing policies or any other roadside vegetation management policies, including plantings and/or clearing of forested cover types adjacent to roadways?

- ◯ Yes
- ◯ No

If Yes, please briefly explain which polices and how they were considered:

Mowing:

Planting:

Cleared of forested cover:

Additional Comments:

12. Which of the following statements best describe the role of deer-vehicle collision (DVC) rates in current roadside vegetation management policies in your state: "At least some of our roadside vegetation management policies were created in response to…"

- ◯ A) a perceived reduction of DVC rates
- ◯ B) a demonstrated (quantified) reduction of DVC rates
- ◯ C) both a perceived and a demonstrated reduction of DVC rates
- ◯ D) None of the above.

13. If a demonstrated reduction was selected in question 12 (B or C), please provide documentation for the quantified reduction in deer-vehicle collision rates (publication, reference, or data source).

14. Do you have a list of recommended plants to revegetate roadsides or in medians that are less likely to attract deer or other large herbivores?

- ◯ Yes
- ◯ No

If yes, could you please provide an electronic copy or an internet access address so that we may review them?

15. What challenges have you experienced in attempting to change or implement new roadside vegetation management policies in your state and what recommendations do you have on how other states might make such changes?

16. Are there any other roadside vegetation management policies or best management practices in your state that are related to DVCs that have not been addressed above that you think would be of value to share with other DOTs?

- ◯ Yes
- ◯ No

If yes, please briefly describe:

Conclusion

Thank you for participating in this survey of roadside vegetation management as it relates to deer-vehicle collisions.

We very much appreciate your contribution.

APPENDIX C

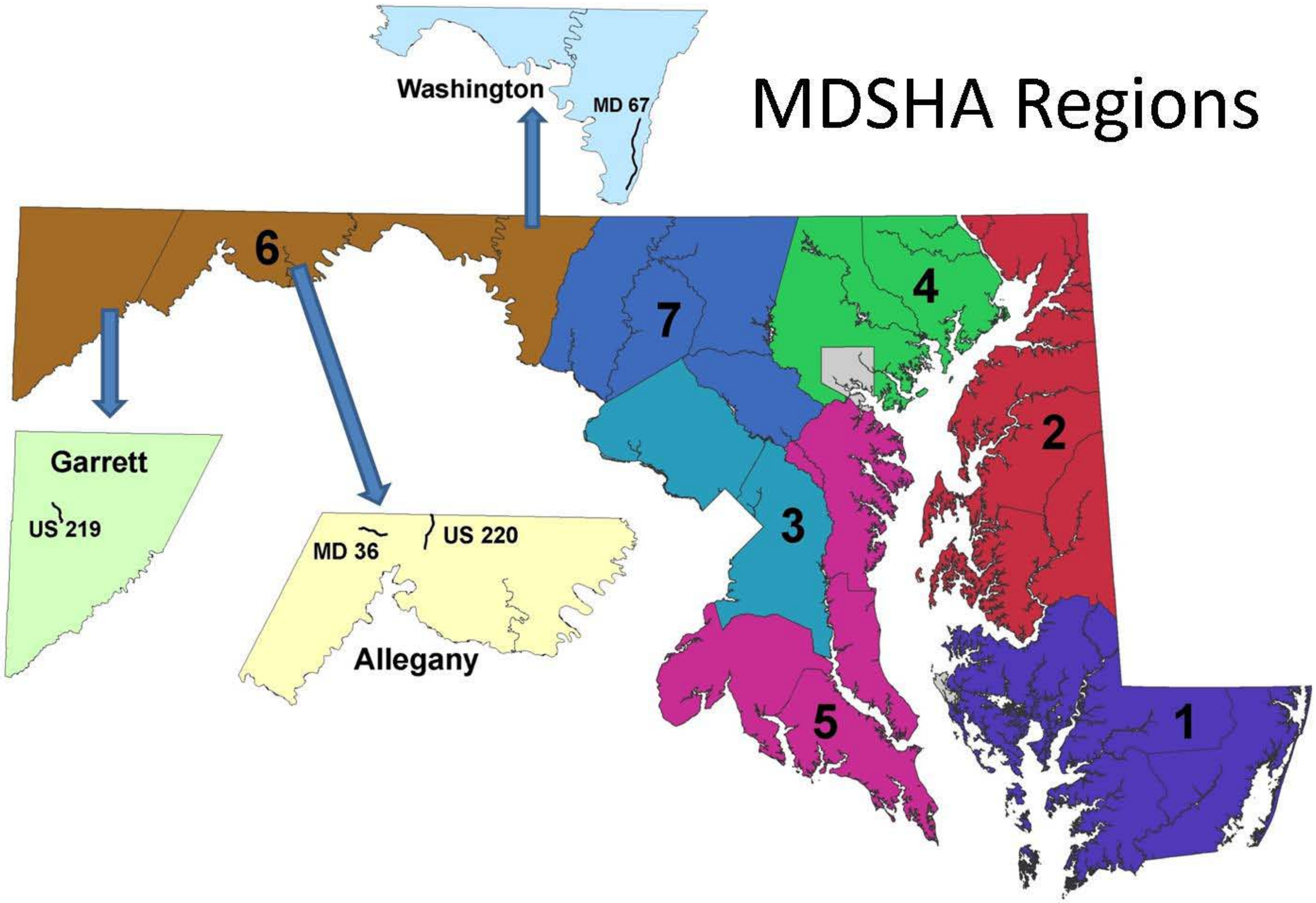

Figure 2. Maryland State Highway Administration Regions and Maryland Counties

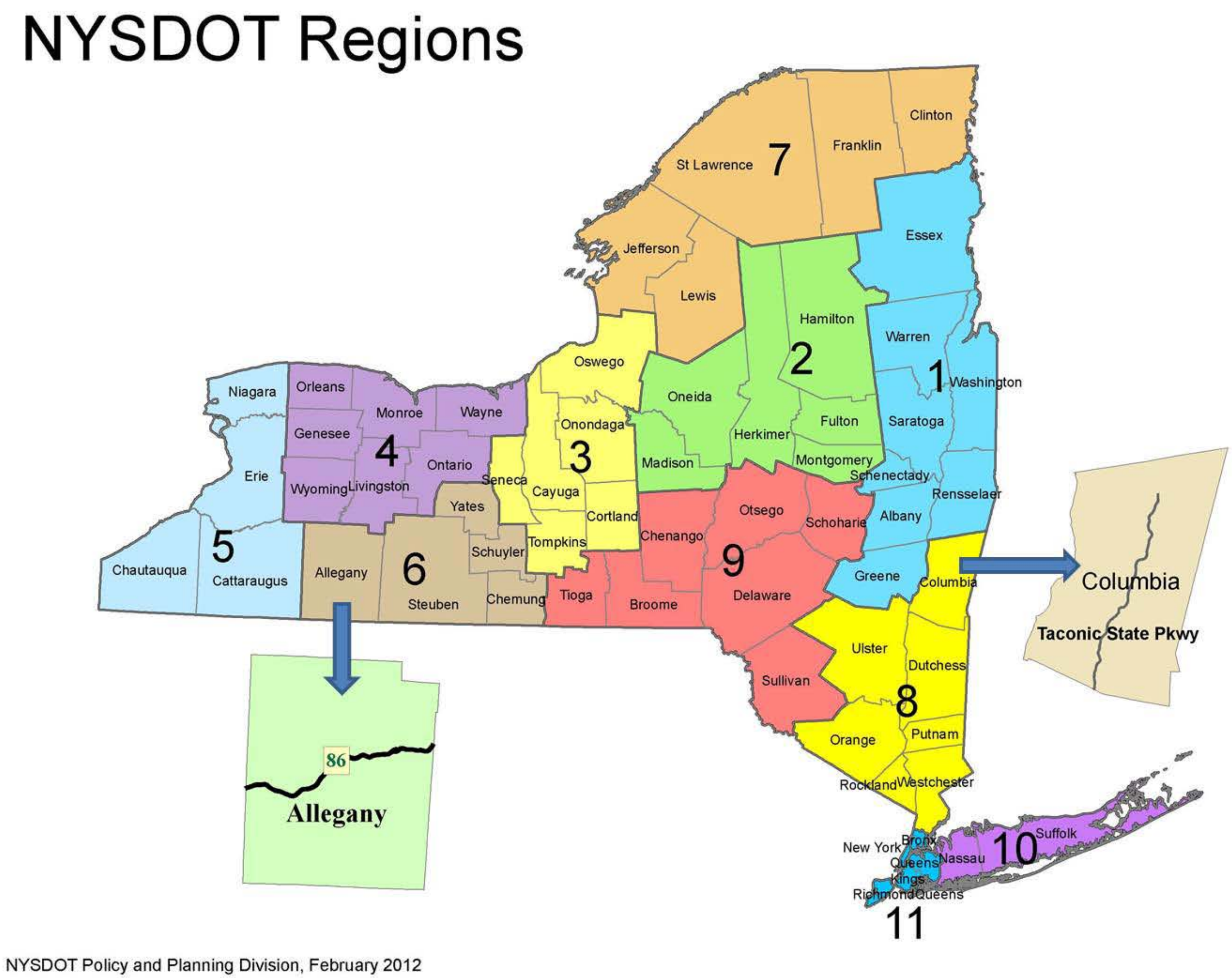

Figure 3. New York State Department of Transportation Regions and New York Counties

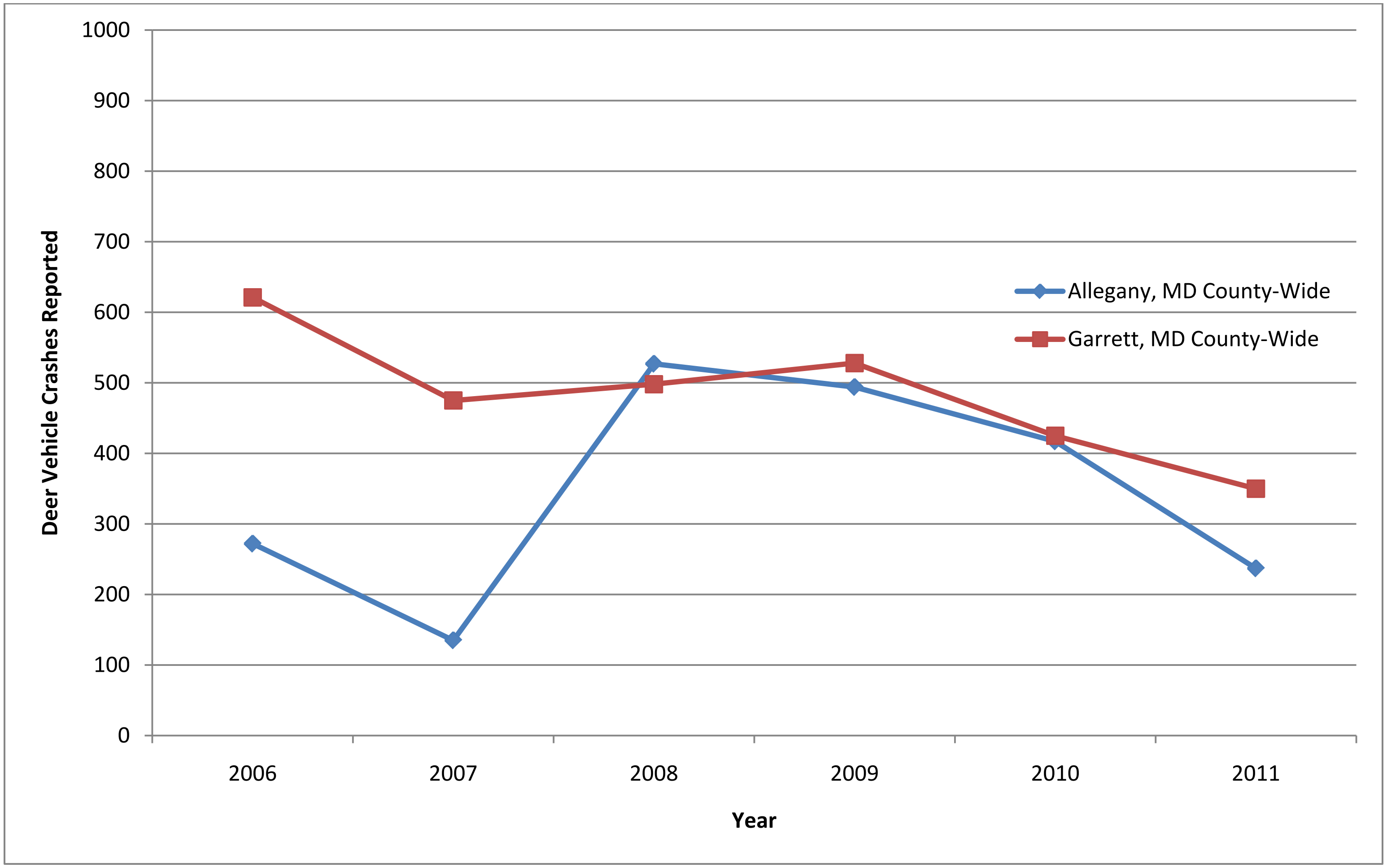

Figure 4: DVC by year across the study period for Maryland county-wide study areas

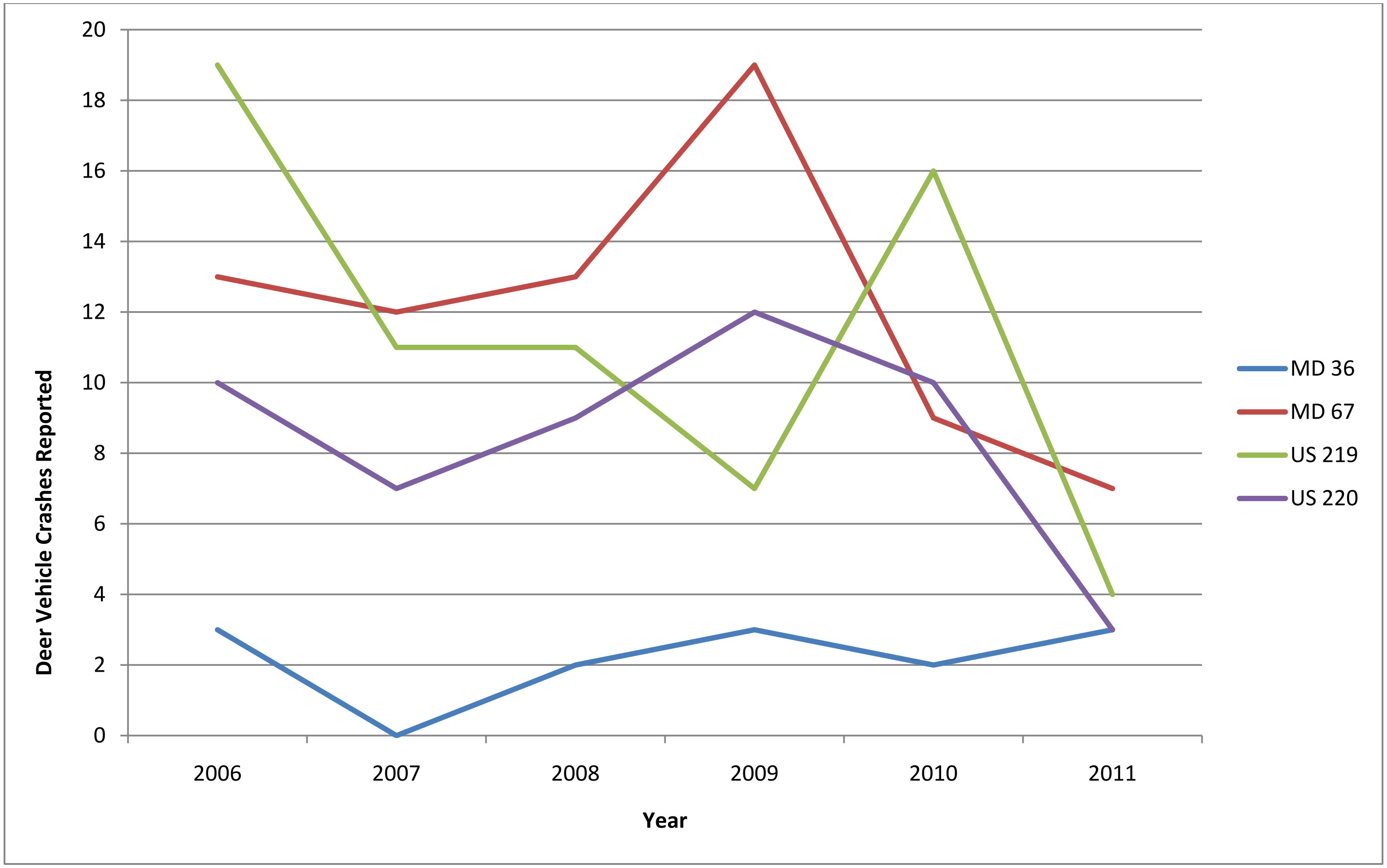

Figure 5: DVC by year across the study period for Maryland focal roadway sections

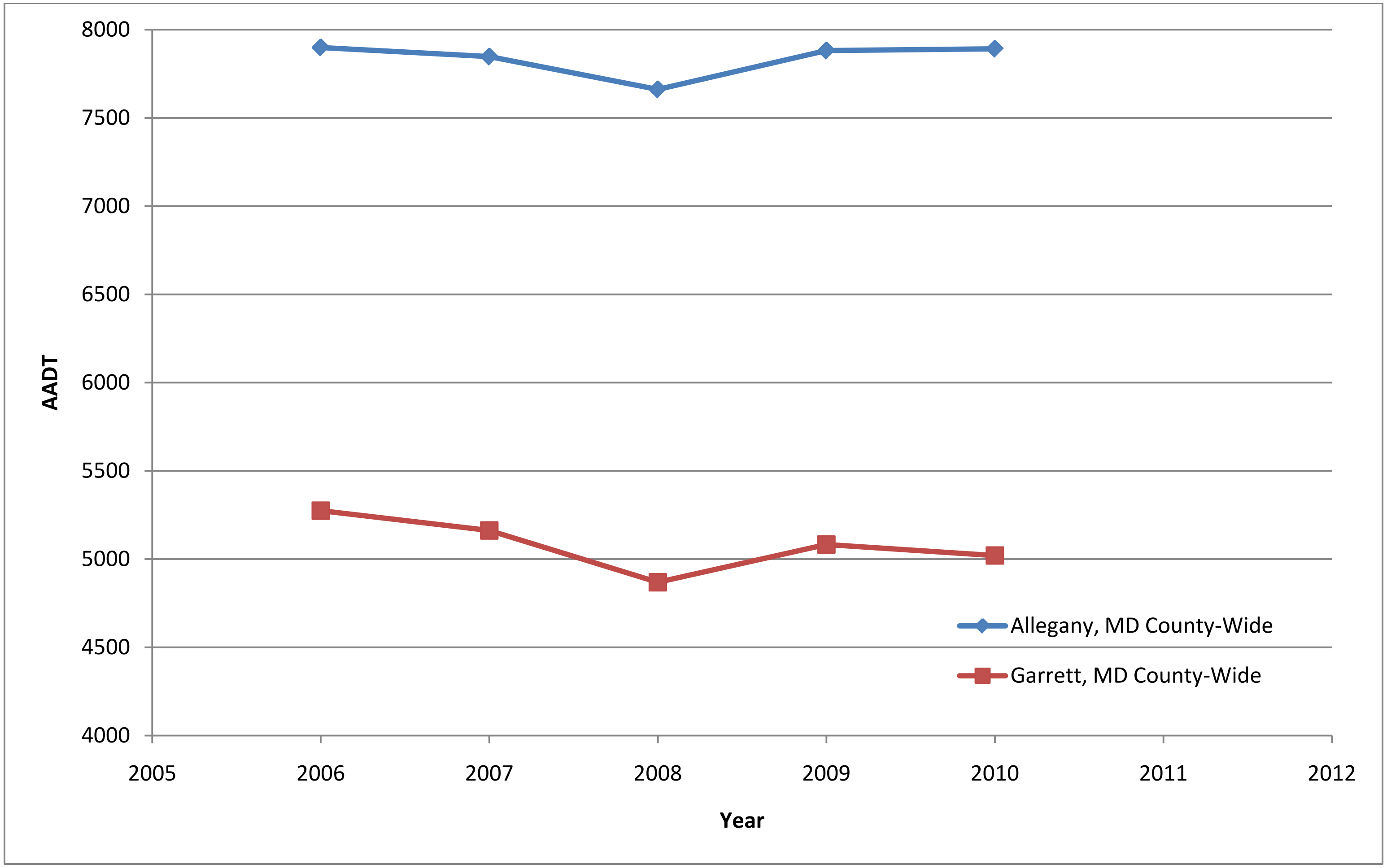

Figure 6. AADT trends by year across the study period for Maryland county-wide study areas

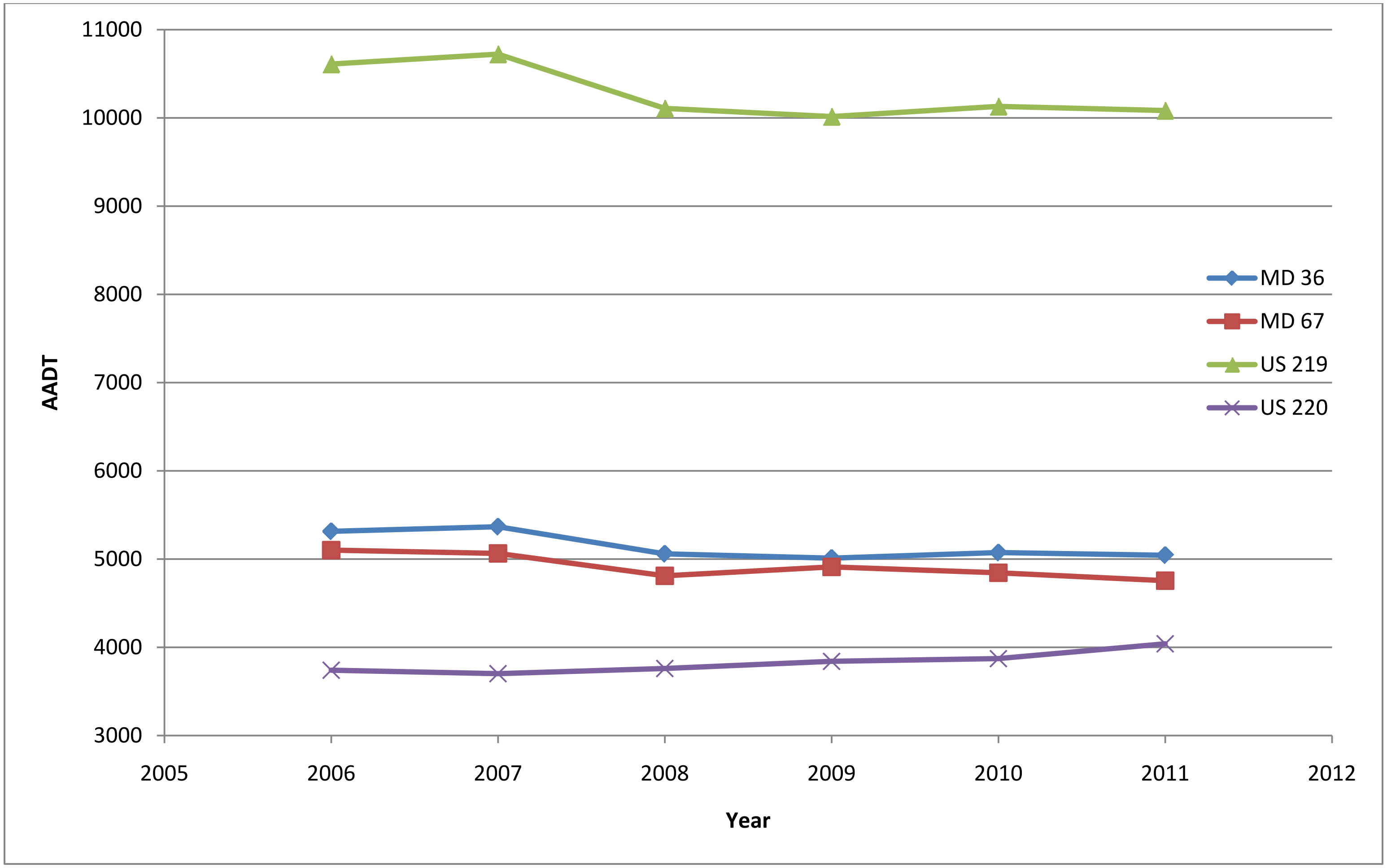

Figure 7: AADT trends by year across the study period for Maryland focal roadway sections

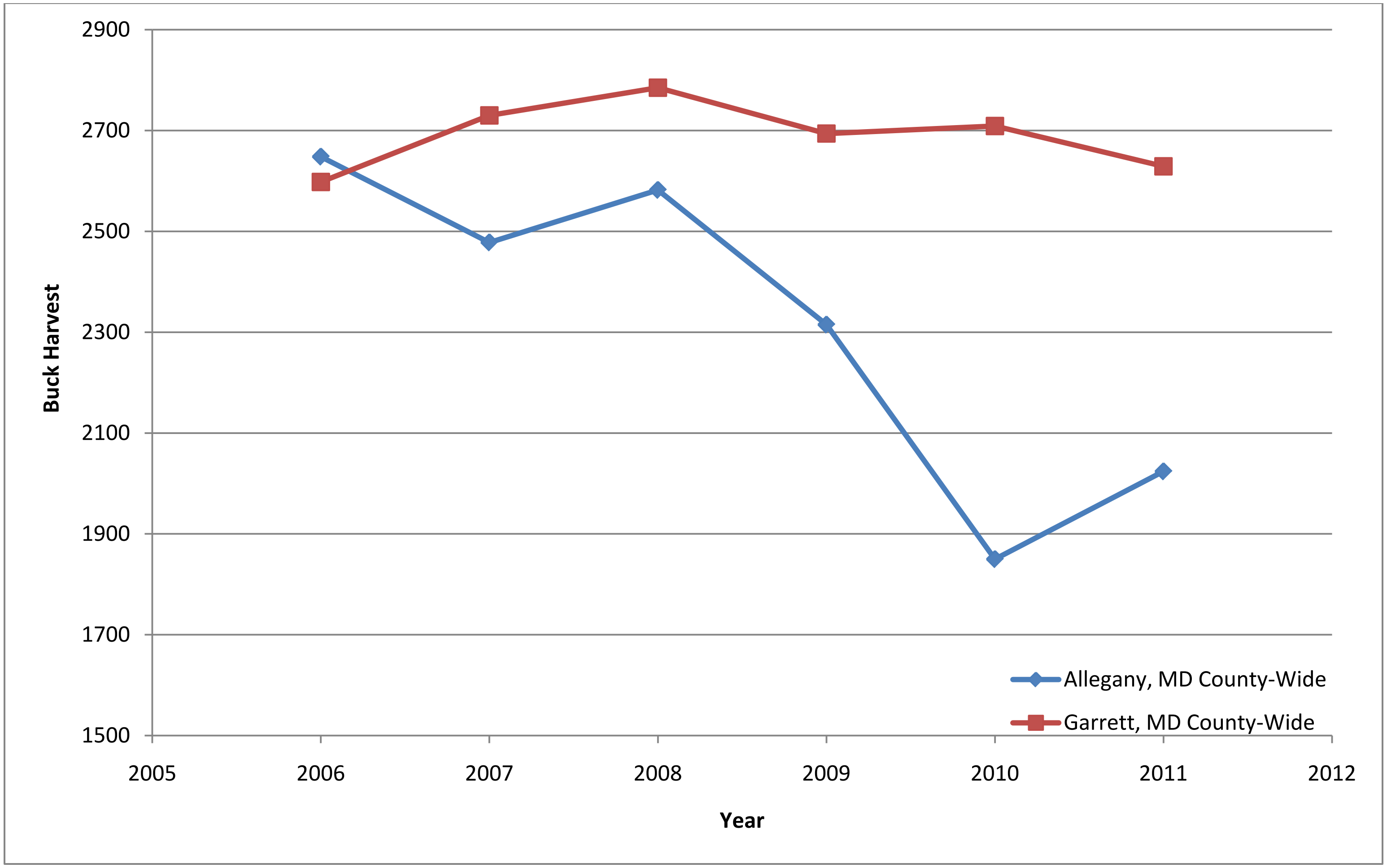

Figure 8: Maryland Buck Harvest by Year in Allegany and Garrett Counties

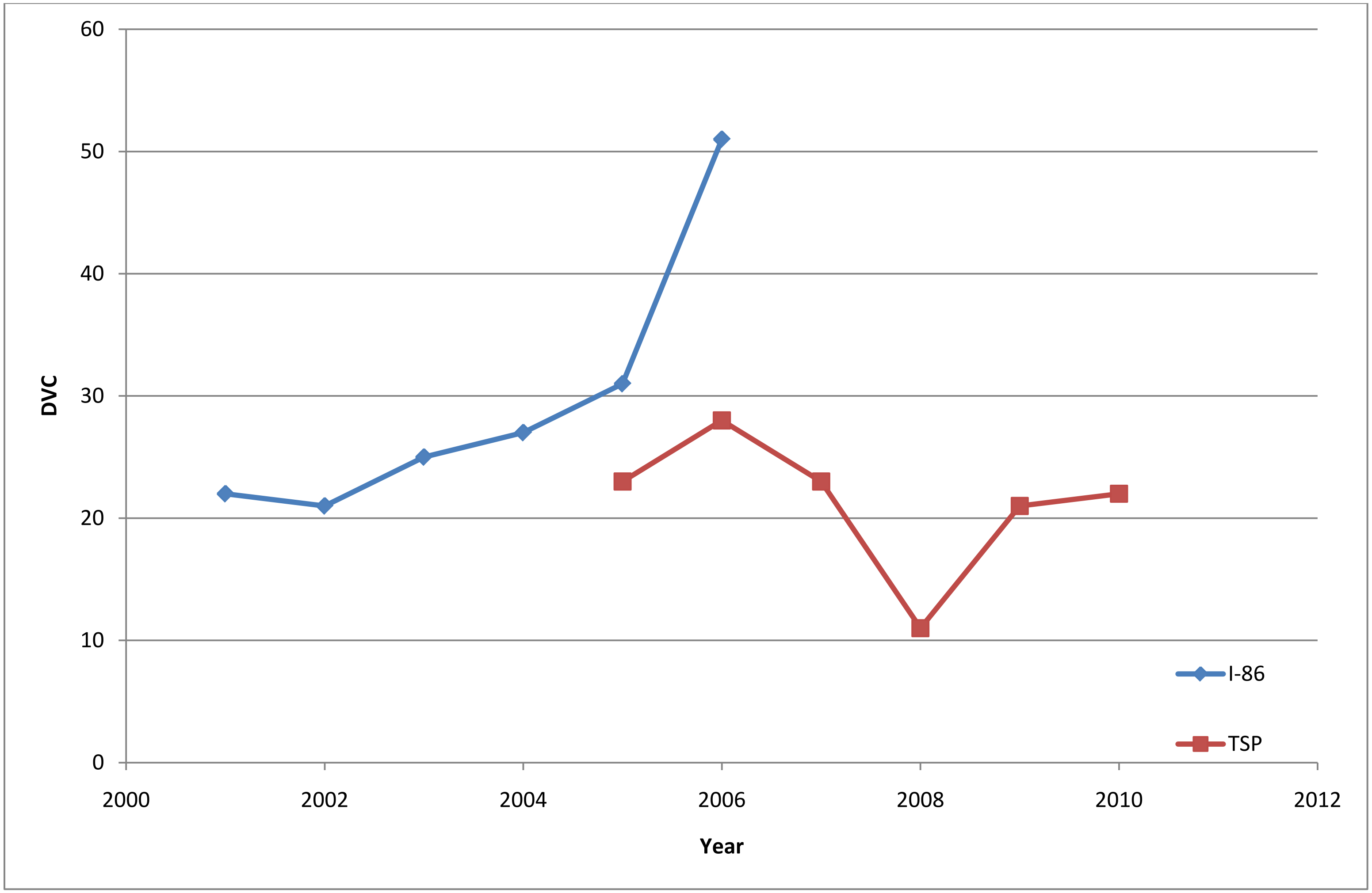

Figure 9: New York DVC by Year on Selected Road Sections

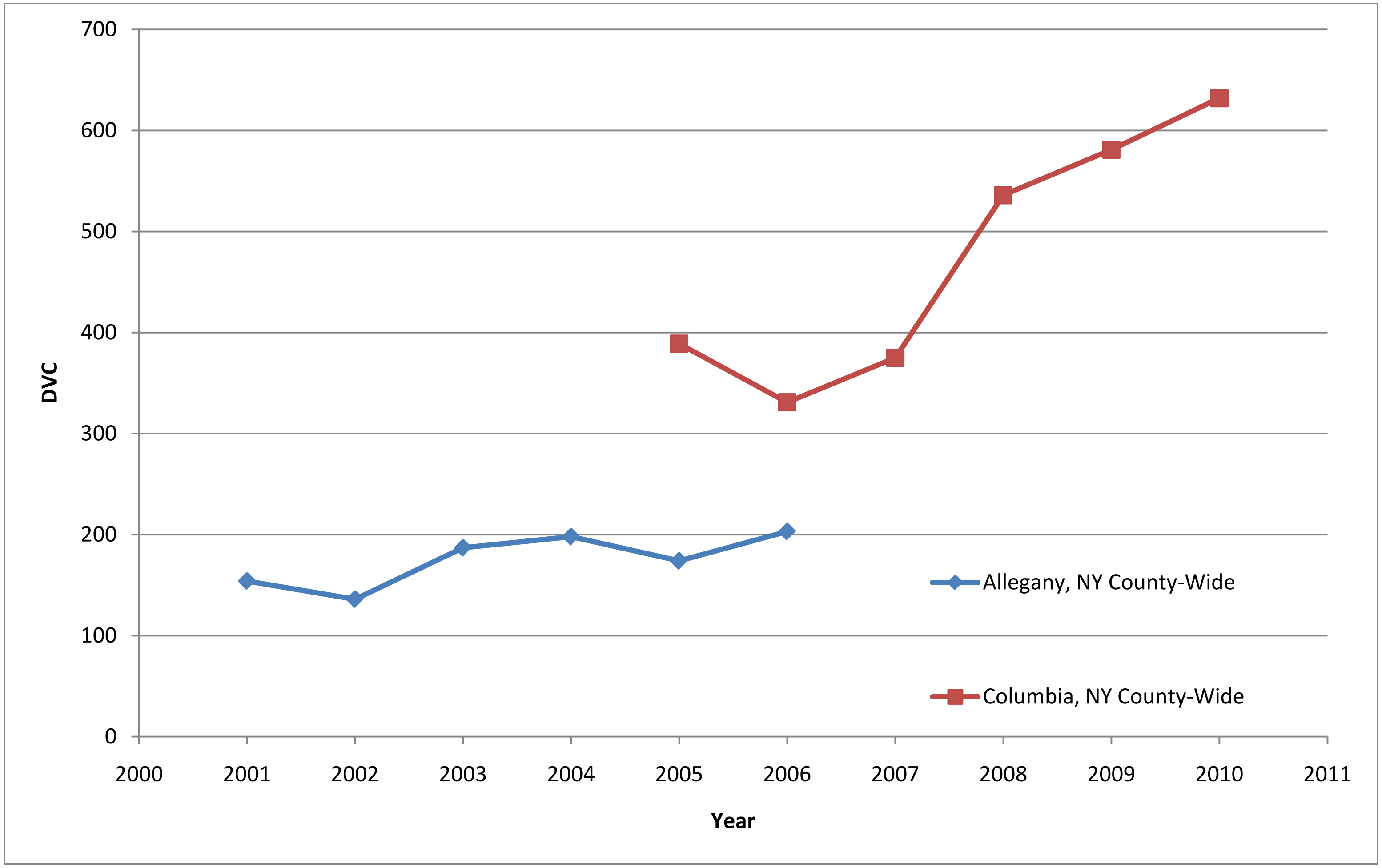

Figure 10: New York DVC by Year in Allegany and Columbia Counties

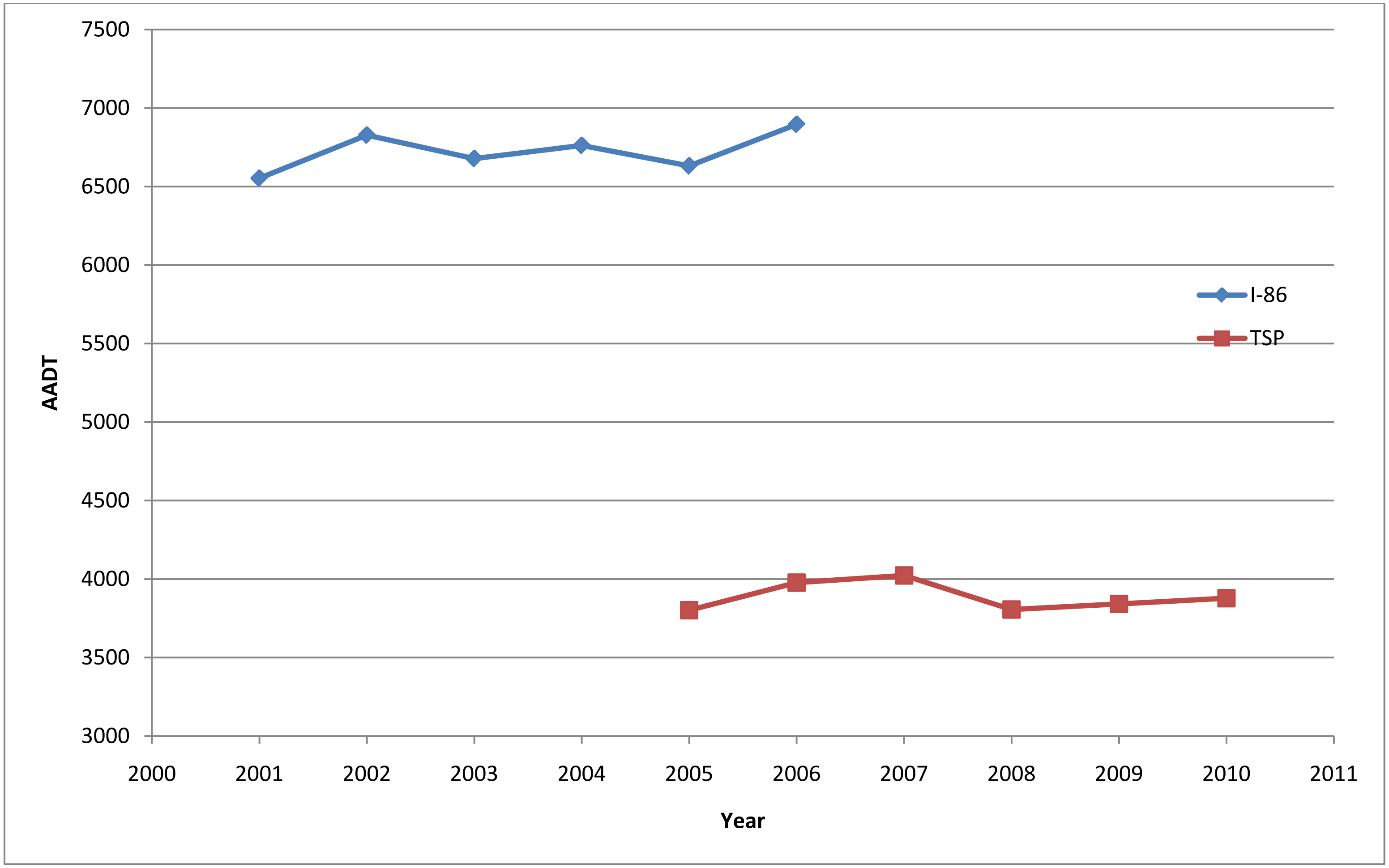

Figure 11: New York AADT by Year on I-86 and TSP

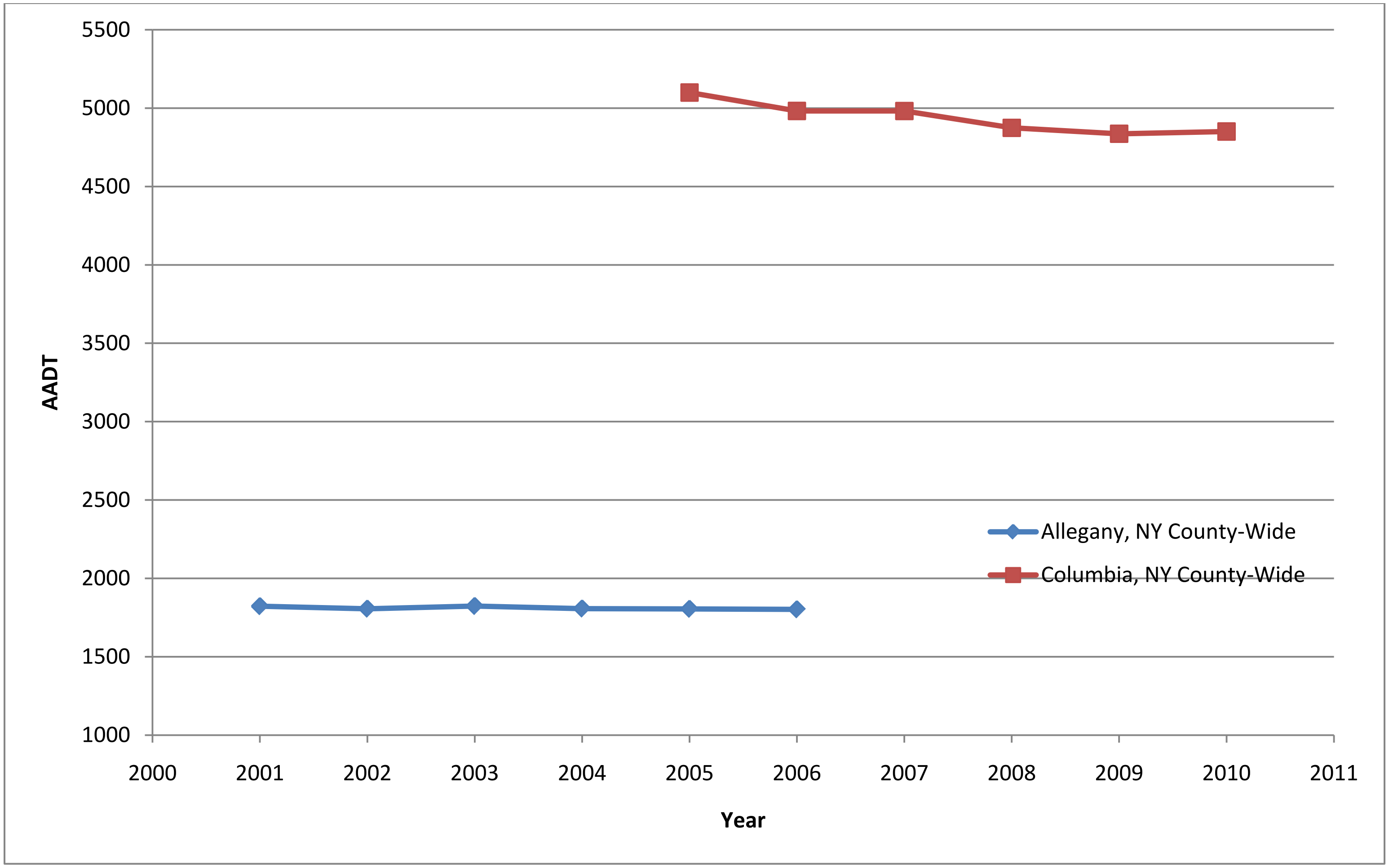

Figure 12: New York AADT by Year in Allegany and Columbia Counties

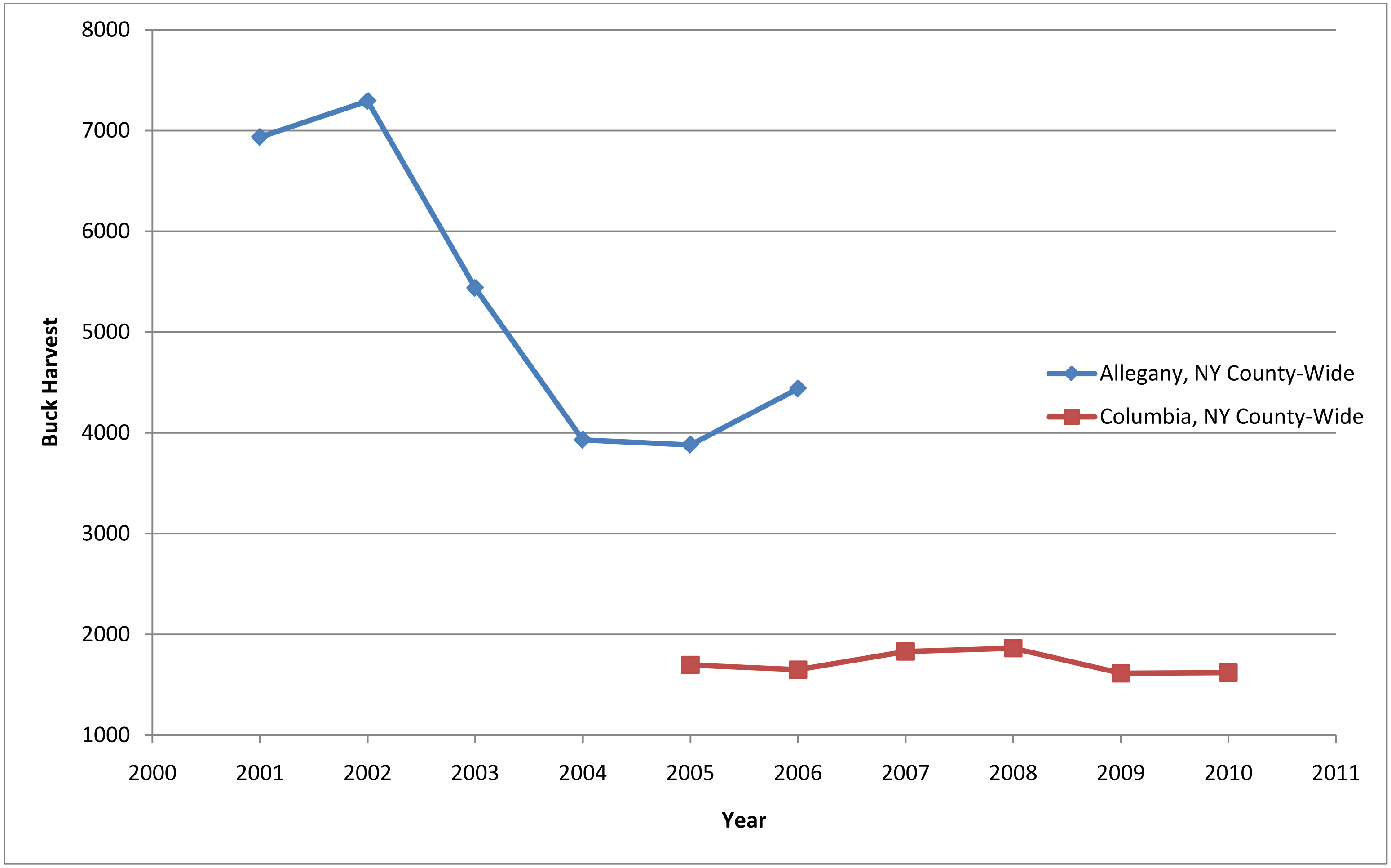

Figure 13: New York Buck Harvest by Year in Allegany and Columbia Counties