HUNTING OR HERD REDUCTION

The number and type of vehicle crashes at a particular location are often directly related to and/or predicted by its exposure characteristics. For example, the Federal Highway Administration recently released a document that included models used to predict the number of intersection crashes per year along two-lane rural roadways (*1*). A primary input for these models are conflicting vehicle flows (an intersection crash exposure characteristic).

In a similar manner, deer-vehicle crashes (DVCs) occur when a vehicle and deer are at the same place at the same time. Two DVC exposure characteristics of a particular roadway location (and time) would seem to include, therefore, measures of vehicle flow and deer crossing the roadway. A plot of deer population and deer carcass data (per hundred million vehicle miles traveled (HMVMT)) for a 30-year time period in Wisconsin is shown in Figure 1 (*2*). In addition, the number of white-tailed deer bucks killed during hunting season has been shown to be highly correlated with the number deer carcasses (one measure of DVCs) collected (*3*). For these reasons, it has been suggested

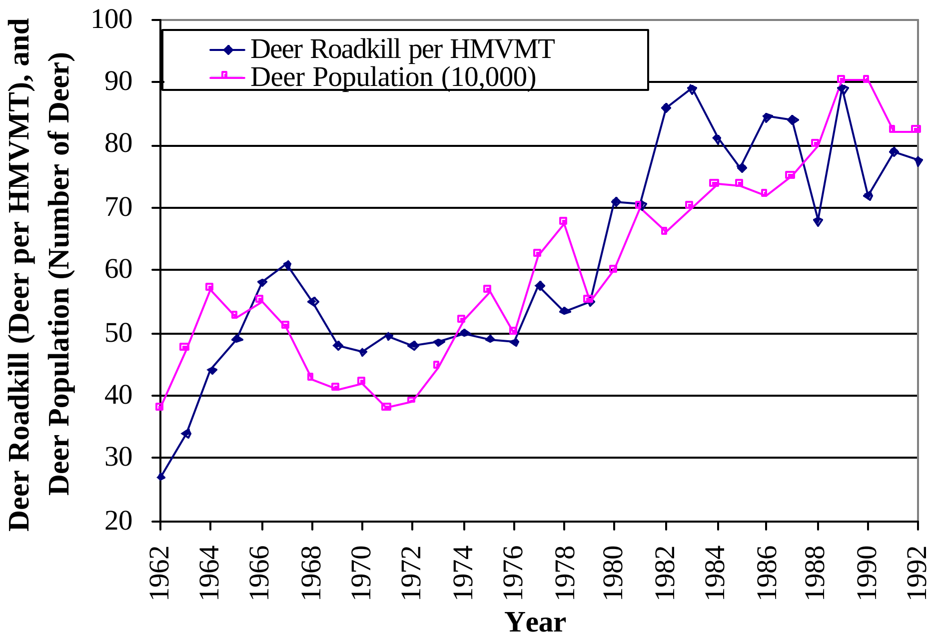

FIGURE 1 Deer roadkill rate and deer population in Wisconsin by year (*2*).

that a reduction in white-tailed deer herd size, through hunting or other means, could be a potential DVC countermeasure.

No studies were found that attempted to quantitatively relate hunting and/or herd reduction activities or policies with a subsequent change in the number of DVCs within a particular large geographic area (e.g., a state). Not surprisingly, the primary objective of the hunting or herd reduction studies reviewed for this toolbox was the impact these activities may have had on the animal population of interest. Several papers and reports were reviewed, however, that did document observed DVC patterns while herd reduction activities were being completed within smaller geographic areas (e.g., a park or city). The findings from these and two other white-tailed deer population dynamics studies are discussed in this summary (*4*, *5*, *6*, *7*, *8*, *9*, *10*, *11*). The researchers from the population dynamics studies speculate that the herd reductions could reduce the number of DVCs in the area (*4*, *5*). Several other researchers, however, have discussed and/or attempted to model the relationships between DVC data and a number of deer and human population, vehicle travel, land use, landscape, and/or roadway/roadside characteristics (*12*, *13*, *14*, *15*, *16*, *17*, *18*, *19*, *20*).

DVC Prediction Models

During the last 30 years a number of researchers have discussed and/or investigated the factors associated with the occurrence and location of DVCs (*12*, *13*, *14*, *15*, *16*, *17*, *18*, *19*, *20*). Some of the factors they have identified include: deer population; human population; vehicle-miles-of-travel (VMT); highway miles; and land cover or acreage classified as woodland, farmland, timberland, urban land, rural land, cropland, and forestland (*12*, *13*, *14*, *15*, *16*, *17*, *18*, *19*). For example, Gunther, et al. noted that within their study area the number of mule deer killed along roadways within forested areas was more than expected (*12*). In addition, Bertwistle also observed relationships between roadkill and the particular habitat and/or behavior or animals (*13*).

In other cases, however, researchers have focused on quantifying the relationships and/or correlations between specific ecological, land use, or roadway factors and the number of

DVCs at a location or within a county or city (*14*, *15*, *16*, *17*, *18*, *19*). Models have been developed (often through a multiple regression approach) to predict the probability a location will be a "high" DVC site and the number of DVCs expected to occur within a county or city (*14*, *15*, *16*, *17*, *18*, *19*). Several examples of these models are described in the following paragraphs. Many of the factors included in these models can be connected to white-tailed deer habitat or movement in some manner.

"High" DVC Location Models

Several projects that examined the potential relationships between "high" DVC locations and their adjacent environmental, roadside, and roadway characteristics were recently summarized and included in a University of Wisconsin thesis (*20*). Models from Illinois, Iowa, Pennsylvania, and Kansas are discussed below (*14*, *15*, *16*, *17*).

The Illinois Model In Illinois, Finder considered the percentage of woodland, forage (i.e., crops, fields, and orchards), developed land, and water within a 0.8 kilometer (0.5 mile) buffer of 1.3 kilometer (0.8 mile) roadway segments with more than 15 reported DVCs between 1989 and 1993 (*14*). She also investigated characteristics related to right-of-way topography (flat, gully, and bank), roadway segment curvature (a ratio of total length to straight length), general buffer area topography (the difference between the highest and lowest contours), the number of fields in the buffer area, the deer travel corridor width (i.e., the typical width of corridor that deer use to travel within their home range) across the roadway, and the distance from the roadway to the nearest forest cover and parks (*14*).

Data from 81 "high" DVC locations and 81 control sites within 43 counties were used to develop two models to calculate the probability a roadway location would be a "high" DVC site (*14*). The first Illinois model included all variables found to be significantly different between the "high" DVC and control sites (*14*). The model indicated that the probability a roadway segment would be a "high" DVC site decreased as its distance from woodlands increased (*14*). This probability increased with the percentage of adjacent gully, nearby recreational areas, and the width of the deer travel corridor across the roadway (*14*). Only landscape variables were incorporated into the second model, and it showed that higher values of Simpson's diversity index (a measure of land cover richness (i.e., number of different landscape patches) and uniformity), and woodlands mean proximity index (a measure of woodlands patch size and density) increased the probability of a roadway segment being a "high" DVC site (*14*). Finder proposed that a site be considered a "high" DVC location if the model output was greater than 0.60 (*14*).

The Iowa Study Hubbard, et al. also studied the relationships between several roadway and roadside factors and the probability a roadway segment could be a "high" DVC location (*15*). They considered the characteristics of 1,284 locations randomly selected within Iowa, and defined any one mile roadway segment with greater than 14 reported DVCs between 1990 and 1997 as a "high" DVC site (*15*). Hubbard, et al. evaluated data that described certain land cover, daily traffic volume, the distance to the nearest town and nearest city with a population greater than 2,000, the number of bridges along the segment, and the number of roadway lanes (*15*). Eight years of data were used, and the proposed "high" DVC location probability model included measures related to grass, crop, and woodland patches; the variability in land cover patches; and the number of bridges and lanes along the roadway segment (*15*).

The number of bridges within the roadway segment and the number of roadway lanes appeared to be two of the more important predictors of "high" DVC sites in Iowa (*15*). The probability of a "high" DVC site occurring increased with both of these variables, and also the size of nearby grass and woodland patches. The probability of a roadway segment being a "high" DVC site, however, appeared to decrease as the variation in nearby patch sizes and the size of crop fields increased (*15*). A validity test of the model correctly classified 160 (or about 65 percent) of 245 randomly selected sites as "high" DVC or control locations (*15*).

The Pennsylvania Study Finally, Bashore, et al. considered the environmental and traffic flow characteristics of "high" DVC locations along two-lane highways in Pennsylvania between July 1979 and October 1980 (*16*). Roadway segments that were

250 meters (825 feet) long were considered “high” DVC locations if they had a minimum of four DVCs reported in the year preceding the study and at least two reported DVCs per year in 5 of the 10 years preceding the study (*16*). Some of the roadway and habitat (within 100 meters (328 feet) of the roadway) variables considered for this model included: number of residences; number of commercial buildings; percent terrain classified as banks, gullies, and level; percent land cover classified as wooded, non-wooded, and barren; distance to woodlands greater than 0.8 square kilometers (0.25 square miles) in area; three percent slopes classifications; sight distances along the roadway and in-line visibility (i.e., the distance at which an observer one meter (3.28 feet) from roadway centreline can no longer see a two meters (6.56 feet) high board on the roadway edge); posted speed limit; fencing within the buffer area as a percent of segment length; and guardrail length as percent of the segment length (*16*).

Data from 51 “high” DVC and 51 control sites were used to develop the Bashore, et al. model, and it included variables that measured the number of homes, commercial, and other (e.g., hunting camps, churches, and barns) buildings within the buffer area of the roadway segment, roadway sight distance and in-line visibility, posted speed limit, the distance to woodlands, and the proportion of fence length and non-wooded herb areas in the buffer zone (*16*). The predicted probability decreases with an increasing number of homes, commercial, and other buildings within the buffer area, and longer sight distance along the roadway (*16*). The model also indicates a decrease in the “high” DVC probability with increases in the percent fencing, the distance to woodlands, the ability to see a roadside object (i.e., in-line visibility), non-wooded herbs in the buffer zone, and posted speed limit (*16*). The researchers speculated that the negative relationship between posted speed limit and the probability of a “high” DVC location might be because fewer deer may cross when vehicles move at higher speeds (*16*). They suggested that a “high” DVC site should have a model output of 0.70 or greater (*16*). Issues related to the potential intercorrelations between input variables included in this and other models are discussed in the conclusions section of this summary.

The Kansas Study Researchers at the University of Kansas also recently completed work that identified variables or parameters that appear to be correlated with the DVC experience of a roadway segment (*17*). They developed a model to predict DVCs per year per mile of roadway, and considered input data from 45 roadway, roadside, and deer population factors (e.g., land use type, deer harvest density, sideslope, traffic volume, posted speed, etc.) (*17*). The results indicate that the variable most strongly correlated with DVCs per year per mile was the existence of wooded land adjacent to the roadway (*17*). DVCs per year per mile were also positively correlated to the number of roadways lanes, traffic volume, posted speed, number of bridges and/or visible culverts, the presence of a deer warning sign, and traditional right-of-way fencing (*17*). Factors negatively correlated with DVCs per year per mile included clear width (i.e., distance to an obstruction at least 3 feet wide and 2.5 feet high), roadside sideslope, and roadside topography in the transverse direction (*17*). In addition, those roadway segments with a grass median had higher DVC rates than those with median barriers, and those with median barriers had higher rates than two-lane undivided roadways (*17*).

County DVC Models

At least two researchers have also developed models to predict the number of DVCs within a county (*15, 18*). In Illinois, Finder studied the relationships between county DVC densities (i.e., the number of DVCs per county land area) and deer habitat, traffic volume, highway length, land ownership, and human habitat factors (*15*). Iverson and Iverson took a similar approach in Ohio, but also examined the relationships between county DVCs and the total land area in the county, and areas classified as urban, rural, cropland, and forestland (*18*).

Illinois Study Finder studied the number of state highway DVCs reported from 1987 to 1994 within each Illinois county (*15*). She used a multiple regression approach to develop a model to predict county DVC density, and considered data related to the following potential input variables:

- County deer density;
- County human density;
- Urban and rural roadway miles per county area;
- Average daily vehicle kilometers of travel per county area;
- Percent county land area closed to hunting;
- Percent county acreage of timberland in federal, state, county and private ownership;
- Percent county acreage of farmland; and
- Percent county acreage of woodland (*15*).

The model proposed by Finder to predict county DVC density included measures of human density, deer density, and farmland, privately-owned timberland, and woodland acreage (*15*). The predicted countywide DVC density increased with both human and deer densities, and the amount of privately-owned timberland. The predicted DVC density decreased with increases in the percentage of woodlands and farmland. Finder speculated that the percentage of woodland acreage in a county might be intercorrelated in some form with roadway mileage, human density, and the amount of farmland. For example, as the amount of woodland increases in a county the amount of roadway mileage, human density, and farmland appeared to decrease. These variables, however, remained in the final model proposed (*15*). This issue is discussed further in the conclusions portion of this summary.

Ohio Study In Ohio, Iverson and Iverson analyzed the number of reported DVCs in 88 counties from 1995 and investigated the relationships between these data and the following variables:

- County deer harvest (number of deer killed in hunt),
- Total county roadway length,
- Total county land area,
- County forest land area,
- County rural land area,

- County urban land area,
- County cropland area, and
- County human population (*18*).

The model developed to predict the annual number of DVCs in a county included the total length of roadway, and the total amount of land area, urban land area, and cropland in the county (*18*). The predicted frequency of annual DVCs increased with all these variables except cropland. A DVC density (i.e., DVCs per 100 hectare) model was also developed, and included measures of cropland, forestland, and urbanized land as input. Intercorrelations between these variables would seem to exist, but the model indicated that DVC density decreased with the amount of cropland and forestland in a county, but increased with the amount of urbanized land (*18*). The intercorrelations between these model inputs were not extensively discussed in the report, but it was speculated that fewer deer would exist with increases in cropland (*18*).

Urban Area Model

Another investigation of the variables related to DVCs was also recently documented, but this study focused on landscape factors within an urban environment (*19*). Clayton, et al. evaluated and quantified the relationship between a series of 66 landscape variables and the DVCs in Bloomington and Maple Grove, Minnesota (two suburbs of Minneapolis) (*19*). The DVC data evaluated was from 1993 to 2000, and eighty 0.5 kilometer (0.62 mile) roadway segments (including 0.1 kilometer (109 feet) on each side of the roadway for the landscape variables) with 2 or more reported deer carcass permits were identified along with 80 random control segments with 1 or fewer reported deer carcass permits (*19*). The variables that best explained the difference between the DVC and control segments were the number of adjacent buildings and public land patches (*19*). The DVC segments contained fewer buildings and more patches of public land (*19*). A validation test of the logistic regression model developed with these two input variables produced a correct classification for 77.5 percent of the 40 validation locations considered (*19*). It is suggested by Clayton, et al. that this type of information could be useful to wildlife biologists and urban planners to manage white-tailed deer habitat within urban areas (*19*).

No conclusions were documented that addressed the impact the potential intercorrelation between the number of building and public land patch input variables, and the impact that might have on the usefulness of the model. The researchers did acknowledge that the public lands observed had few buildings and little human presence (*19*).

Hunting and DVCs

The studies previously described show that many factors, including the number and/or density of deer, appear to influence the number of reported DVCs at a particular location or within a particular area. In addition, many of the input variables (e.g., amount of woodlands) in the predictive models developed can often be related to the expected population, behavior, and/or movements of white-tailed deer. In fact, it has also been shown that management of or changes in white-tailed deer habitat can have herd reduction impacts in addition to typical hunting or herd reduction activities (*21*). However, the use of public hunting or other activities/policies to manage a white-tailed deer herd to proper and supportable densities is a generally accepted approach and widespread application throughout the United States. The white-tailed deer population and DVC impacts from the introduction of a hunting season and other herd reduction activities within small geographic areas (e.g., parks, reserves, and cities) are described below (*4*, *5*, *6*, *7*, *8*, *9*, *10*, *11*). Unfortunately, no studies were found that attempted to define the relationship between large-area (e.g., statewide) hunting policies that may result in lower white-tailed deer densities and a subsequent reduction in DVCs. This type of large-scale causal chain would be difficult to quantify, and most likely require a long-term evaluation in one state and/or a comparison of impacts in multiple states with differing herd management approaches. DVC and/or deer carcass numbers, however, are considered as input by several state agencies to their herd management decisions or population goals.

Population Dynamics Studies

The focus of two studies reviewed for this summary was the impact an introduction of hunting might have on the white-tailed deer population (*4*, *5*). The documents that summarized this impact also described the impact or interactions these actions appear to have on the number of nearby DVCs. For example, Lamoureux, et al. studied white-tailed deer population dynamics and found that DVCs were a principal cause of deer mortality during periods of no hunting, but that the level of DVCs occurring did not appear to be a concern with respect to herd population (*4*).

In 1993 the hunting season in two large white-tailed deer wintering areas was closed due to population concerns (*4*). In 1996, the hunting season was then reopened because it was felt that the white-tailed deer population had recovered. From 1996 to 1998 the primary causes of deer mortality in the area were hunting (39 percent), undetermined (22 percent), poaching (16 percent,), starvation (13 percent), DVCs (6 percent), and predation (3 percent) (*4*). But, the estimated deer population growth rate during these years was equal to or lower than the rate reported during the hunting moratorium. It was concluded that male-only hunting regulations did not protect female deer from hunting mortality, and hunting apparently had a greater impact on mortality than starvation, predation, DVCs, and other undetermined causes (*4*). The impact of hunting on the pattern of DVCs in the area, however, was not quantitatively considered.

A similar study of white-tailed deer population dynamics was also done in the Oak Ridge Reservation in Tennessee (*5*). Hunting in the reservation (which is surrounded by a 3 meter (9.8 foot) fence) was not allowed for 45 years, but was introduced in 1985 (*5*). The study period for this hunting impact evaluation was from 1985 to 1994, and the number of deer killed by vehicles during this time period decreased from 273 to 143 (*5*). The number of deer harvested in the area also decreased from 923 to 470 (*5*). It was concluded that the almost 50 percent reduction in DVCs was an indication that the white-tailed deer population in the area had been intensely hunted (*5*). In addition, the researchers also believed that the number of DVCs before hunting was allowed in the area had been the primary reason the white-tailed deer population had reached equilibrium below its ecological carrying capacity (*5*).

Herd Reduction Activity Studies

One goal of herd reduction activities within smaller geographic areas (e.g., a metropolitan city or park) is often the reduction of DVCs. In fact, in addition to vegetation damage, DVCs appear to one of the primary reasons herd reduction activities are proposed and/or started in urban areas. A number of urban herd reduction activities (e.g., additional hunting, professional sharpshooters, live trapping and release, and sterilization) have been documented, but only a few of the summaries include data related to the monitoring or evaluation of their potential DVC impacts (*6*, *7*, *8*, *9*, *10*, *11*).

For example, the potential DVC impact of introducing hunting in Princeton Township, New Jersey was recently documented (*6*). It was concluded that gun hunting could be used to control deer populations in the area and that this reduction should reduce DVCs (*6*). However, little quantitative evidence was offered to support the latter portion of this conclusion (*6*). Another author, describing the same area in an earlier document, had shown that the DVCs in Princeton Township (which has a no-firearms-discharge ordinance) increased 436 percent from 1972 to 1982, but that DVCs in the two adjacent townships (which had firearms hunting) had not experienced a statistically significant change (*7*).

Similarly, herd reduction activities have been documented within county forest preserve land in Northeast Illinois, the Town of Irondequoit, New York, the City of River Hills, Wisconsin, and Bloomington, Minnesota (*8*, *9*, *10*, *11*). White-tailed deer population reduction was completed during the mid- to late-1980s within the Ned Brown Forest Preserve or Busse Woods (*8*). The reductions were accomplished by sharpshooters, rocket-netting, and drive-netting (*8*). The objectives of the reduction were to increase vegetation, reduce DVCs on adjacent roadways, and improve the condition of the herd (*8*). It was found that the DVCs on adjacent roadways decreased from 37 in 1982 to 13 or fewer per year after 1987 (the year the herd density goal was reached), but no statistical analysis or DVC data variability discussion was included in the document (*8*).

Herd reduction activities in the Town of Irondequoit, New York included a selective culling program, and a live-capture and translocation process was used in River Hills, Wisconsin (*9*, *10*). Sharpshooters have been used within Irondequoit's Durand Eastman Park and adjacent public lands since 1993 and the town introduced a controlled archery hunt in 1996 (*9*). The sharpshooters have culled 845 deer and the archery season 240 deer (*9*). The total number of DVCs from 1993 to 2000 was 534, but in 1992 (before the culling program) the number of DVCs was 227 (*9*). In 2000 it was estimated that the number of DVCs was around 100 (*9*). However, the general variability of the DVC data was not discussed (*9*). The authors of the summary concluded that the DVC data could represent another measure of the white-tailed deer herd size (*9*). The live-capture and translocation activities in River Hills began in the winter of 1987 and 1988 (*10*). These activities were approved in the city because of concerns related to vegetation damage and DVCs (*10*). A total of 438 deer were captured in River Hills and relocated between 1987 and 1992 (*10*). The number of DVCs in River Hills had generally increased from 1980 to 1989, but has experienced a decline since 1989 (despite an increase in traffic flow) (*10*). The peak number of annual DVCs within River Hills between 1980 and 1992 occurred in 1989 (*10*). It is estimated that the cost per white-tailed deer captured within the program was between $300-$400, and that the success of the program was at least partially due to the insular nature of the River Hills herd (*10*).

From 1991 to 1993 four methods of herd reduction were also used on the white-tailed deer population in Bloomington, Minnesota (*11*). The methods used were controlled hunts, opportunistic sharpshooting by conservation officers, sharpshooting over bait in a county park, and sharpshooting over bait in small public land areas (*11*). It was concluded that these four programs reduced the white-tailed deer density by 46 percent and DVCs (measured by carcass possession permits issued) by 30 percent in the area (*11*). The herd density goal was reached in 1993, but the 30 percent reduction in DVCs only occurred between1992 and 1993 (*11*). The number of DVCs actually increased the first two years of the program, and the annual number of DVCs in 1989 was also lower than that occurring during 1993 (*11*). This natural variability in DVCs or DVC-related data was not addressed in the document reviewed.

Conclusions

The relationship between specific hunting policies or activities and their impact on white-tailed deer population is generally acknowledged. However, the impact of these same policies or activities on the number of DVCs that occur along roadways within the managed area has not been studied in a quantitatively proper and comprehensive manner. This is not surprising because the primary objective of many herd reduction or hunting studies is not DVC reductions. Researchers that have investigated herd reduction and/or hunting activities have focused on their impacts on the white-tailed deer population, and then suggested that the reduction in deer population or density caused by these activities should lead to a reduction in DVCs. The number of DVCs is sometimes used as an input to large-area herd management decisions, and the reduction in DVCs is always a desirable outcome of these decisions. In urban areas, a reduction in DVCs is often the reason herd reduction activities are initiated.

The suggestion that a reduction in the white-tailed deer herd should lead to fewer DVCs appears to be at least partially supported by the input variables included in the DVC predictive models discussed in this summary. The "high" DVC probability and county DVC frequency or density models described all appear to include some direct or indirect measure(s) of deer population, habitat, and/or movement. The cause-and-effect relationship between these measures, herd reduction and/or hunting activities/policies, and the occurrence/pattern of DVCs, however, has not been quantified in a proper manner. In general it should be recognized that models developed through a multiple regression approach define a statistical data correlation, but may not describe a cause-and-effect relationship (*1*). In addition, caution is advised when a proposed model appears to include intercorrelated input factors (which by definition are supposed to be "independent") and/or modeled coefficients that seem to be illogical (e.g., reductions in DVCs with an increase in posted speed limit). The intercorrelation of input factors in a model makes it difficult (or impossible) to interpret the actual magnitude and direction of individual variable impacts on model output (*1*). This interpretation problem can occur even if the model appears to produce “reasonable” results (*1*). These types of issues should to be considered as the models described in this summary are used.

There is a need for a focused study of the causal connections between hunting or herd reduction management policies and their potential impact on DVCs. The small area studies described in this summary suggest promising results, but the DVC data from these studies (and future studies) should be more properly evaluated. The natural variability of DVC data needs to be properly considered for valid conclusions to be made about the DVC reduction impact of specific herd reduction activities. The results from a properly designed small area study might also be expanded to provide an adequate indication of what could occur over a larger area. It is suggested that the creation of predictive models for DVC frequencies and “high” DVC probabilities continue to be developed with the recognition and/or control of those input variables that may be intercorrelated. The intercorrelations that exist between variables that may impact the occurrence and number of DVCs at a location need to be better defined.

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