GIS Analysis: Steele County Deer Vehicle Collisions

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Abstract

Throughout the Midwestern United States, white-tailed deer vehicle collisions (DVCs) continue to impact many people. The objective of this paper was to spatially and seasonally analyze DVC factors in an agricultural county. Minnesota Department of Natural Resources datasets, unsalvageable carcass and possession permits were used to analyze DVC's in Steele County, Minnesota from 1995 to 2006. ESRI ArcGIS along with Spatial Analyst and Linear Referencing extensions were used to spatially locate re-occurring DVC patterns. Deer seasonal patterns and agricultural seasons were two seasonal factors examined. Spatial analysis revealed Interstate 35 had higher DVC density levels throughout the county. The DVC density levels were especially higher near urban areas. Seasonal analysis found peak DVC occurrences happening during agricultural harvesting season and the deer breeding season.

Introduction

Anyone who has been involved in an accident with a white-tailed deer has experienced a traumatic event. Each year there are more than 1 million deer-vehicle collisions (DVC's), accounting for 29,000 injuries and 200 deaths while costing an estimated $1 billion for vehicle repairs (Conover, Pitt, Kessler, Dubow, and Sanborn, 1995). Expenses not accounted for in this number are medical bills, time spent on highway clean-up and work hours missed.

The Minnesota Department of Transportation (MN DOT, 2010a) estimates 35,000 DVC's annually in Minnesota. MN DOT reports there are 3 to 11 deaths, more than 400 human injuries, and about 4,000 property damage incidents of $1,000 or more each year.

Multiple factors have been related to the level of DVC's. According to Sudharsan, Riley, and Campa III (2009), the DVC rate is related to deer density, habitat, road features, traffic volume, and speed.

The purpose of this study was to analyze the problem of DVC's in Steele County, Minnesota USA using ArcGIS, Spatial Analyst, and Model Builder. The study explored affects of major intersections, urban fringe areas, and deer populations. Furthermore, various seasons, such as crop harvesting, and white-tailed deer patterns were correlated to DVC's.

Finally, the study compared Steele County (Figure 1) to Winona County, a county with prime white-tailed habitat. (Yarnes, 2008). This study also investigated general habitat affects on deer seasonal patterns and DVC's.

Study Area

The study area chosen was Steele County,

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Minnesota USA. Steele County is a rural county, consisting mainly of cropland. According to The Minnesota Department of Natural Resources (MN DNR, 2010) Gap Land Cover dataset, Steele County is 94% cropland/grassland land cover. The county does contain multiple lakes, rivers, forested areas, and a few wildlife management areas all preferred by white-tailed deer. Additionally, there is an abundance of crops, corn, and beans across the county, all preferred white-tailed food sources.

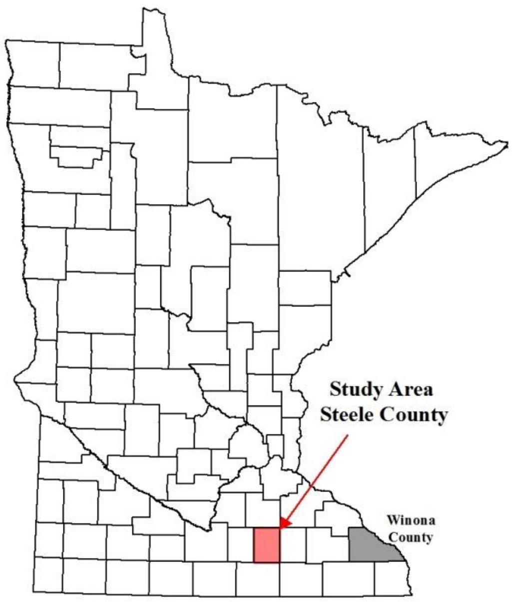

Figure 1. Steele County Location Map.

Steele County has a variety of road types (urban and rural) and major road intersections. Additionally, Interstate 35 travels north and south through the middle of county. It intersects US Highway 14 towards the northern half of the county and State Highway 30 in the southern portion of the county. Figure 2 shows Steele County's major roads, water bodies, municipalities, MN DNR Wildlife Management Areas, and MN DNR deer permit areas.

Data

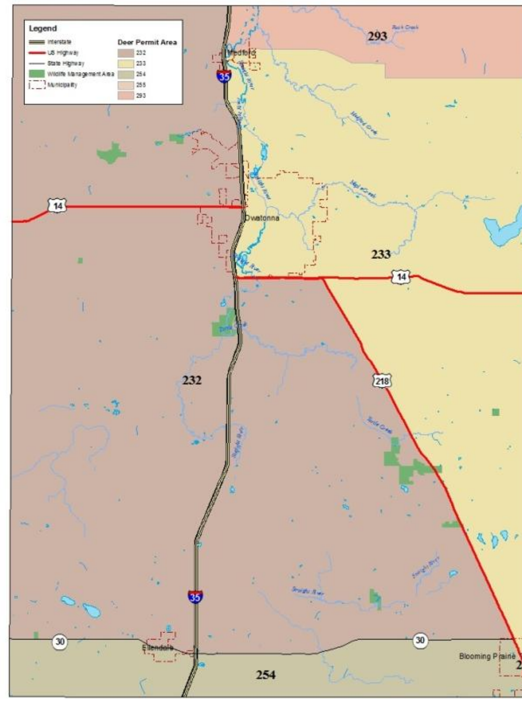

Figure 2. Steele County Features. Scale: 1 inch = 2 miles.

The Minnesota Department of Natural Resources Data Deli and the Minnesota Department of Transportation (MN DOT) were the main sources of data for this study.

Data Descriptions

Deer Vehicle Collision Data

Two primary datasets were used to analyze deer vehicle collisions in Steele County. Brian Haroldson (2010), Wildlife Research Biologist with the Minnesota Department of Natural Resources, provided both. The first dataset, possession permits (PP), contains DVC incidents in which the animal was salvageable and a permit was issued for its keeping. The second dataset, unsalvageable carcass reports (UR), include unclaimed and unsalvageable animals. Both datasets include the years 1995 to 2006.

The datasets contain similar

attributes: date, county, highway, road type, and sex. Where the data differs, the unsalvageable reports contain a more accurate location by providing a mileage location along roadways.

Major Road Data

The roadway data set was obtained from the Minnesota Department of Transportation (MN DOT, 2010b). The Trunk Highway System dataset was downloaded for the entire state. This dataset was chosen because it contained major roads within the unsalvageable reports and there are road mileage fields. Each road segment had a beginning mileage and ending mileage increasing spatial accuracies.

Estimated Deer Population

Minnesota deer population data were obtained from (Grund, 2010). Grund's study provided population estimates per square mile for each permit area from 1998 to 2010. The Minnesota deer permit areas were downloaded from the MN DNR Data Deli.

Traffic Study Information

Traffic study maps were downloaded from MN DOT (http://www.dot.state. mn.us/ traffic/data/maps/thcountymapdex.html). The maps were pdf documents and contained the yearly total traffic count for major road segments throughout the county.

Data Preparation

Data Organization

Before performing the analysis, the data were processed and organized. Data were downloaded as ESRI shapefiles with the coordinate system UTM NAD 83. A file geodatabase was created to store the project files. The downloaded data were imported into a feature data set. An event layer feature data set was created to contain the linear referenced point feature data. The feature data set 'Routes' was created for storing the route layers. Next, a working feature dataset was created to use as a scratch workspace. Finally, to complete the general layer preparation, each feature class was clipped to Steele County's boundary.

Once clipped to Steele County, the deer permit areas square mileage was derived and imported into a spreadsheet to calculate deer population. The total square miles for each permit area, derived from Grund's (2010) population estimates was used to calculate deer population (permit areas do not follow county boundaries).

Next, the DVC tables were processed. A file geodatabase was created for storing the possession permits and unsalvageable reports. These datasets were received in Microsoft Excel spreadsheet form and contained a separate table for each year. Each table was imported into the geodatabase.

The unsalvageable tables differed slightly once imported into the file geodatabase. The mileage field was a string type in some tables and double in others. This created a problem when running analysis processes. Also when converted from Microsoft Excel to ArcGIS, some blank fields were created within the tables. Matching route identifier fields in both the route layer and event table are required. Since there were twelve UR tables, Model Builder was used to process and clean tables.

A model was created to delete blank fields and create the appropriate fields for spatial analysis. A route name identifier field was created and calculated to match the road route identifier. The expression below was created to calculate the road name according to road type.

If x = "INTERSTATE" THEN
y = "ISTH " & [HIGHWAY]
elseif x = "STATE" THEN
y = "MNTH " & [HIGHWAY]
elseif x = "FEDERAL" THEN
y = "USTH " & [HIGHWAY]
else
y = "101MISSED"
end if

Lastly, a mileage field was added and calculated for consistently in storing event mile locations.

Methods

Spatial Analysis

Route and Event Referencing

The first step in spatial analysis was to create a route using the MN DOT major roads layer. A name field was used as the route identifier and was matched in the UR tables. The measure source property was set to contain the layer contains fields for the road segment's beginning mile and ending mile distances. Figure 3 displays the route properties.

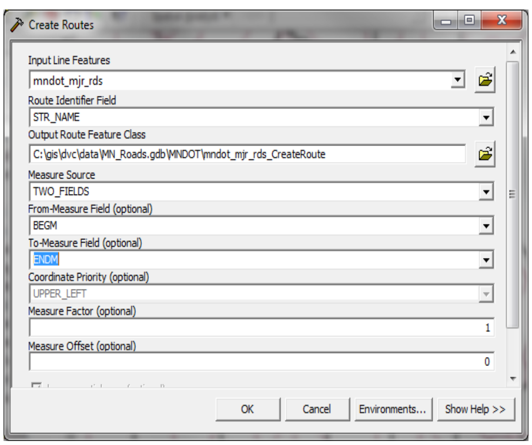

Figure 3. Create Route dialog properties.

Once the route was created, event layers were created for each year of the unsalvageable reports. This was completed using the ArcGIS Linear Referencing Tool 'Make Route Event Layer.' The newly created route was selected as the input route feature. Each UR table contained fields for the name and mileage which, were created in the model processes. The event layers were saved to the feature data set. An example of the tool parameters is shown below (Figure 4).

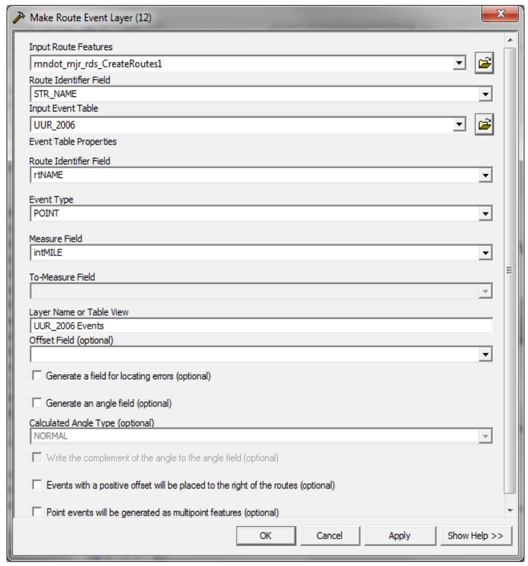

Figure 4. Route Event Layer Dialog Properties.

The unsalvageable reports were now accuratly located as points along the major roads. In order to find DVC hotspots along the county's major roads, density patterns were calculated from these point event layers Spatial Analyst. Kernel density method was chosen to interpolate the density surface. Kernel density allows the user to choose the output cell size and search radius (Figure 5). The output cell size was set to 100 meters, which was an average of the defaults for each event year. Then the search radius was set to 1000 meters so there would be consistancy between each year. Finally, the area units were set to square miles.

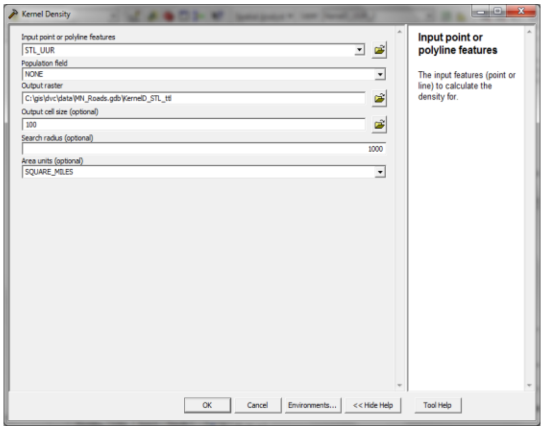

Figure 5. Kernel Density Dialog Properties.

The next step was to normalize each density layer's symbology for analysis. The density surfaces were classified into 3 classes: less than 2, 2 to 5, and greater than 5 UR per square mile. Classifying the densities in this manner, clearly displays the problem areas along the major routes.

Linear Analysis

A linear analysis of the possession permits was conducted. As mentioned previously, the PP reports did not contain specific location. Therefore, a simple analysis along major routes was completed. The first step in the analysis was to generate a continuous major roads layer. The major roads were dissolved. Then possession permit data (1995 to 2006) were summed and attributed to each major road.

Results

Steele County had a total of 1,391 DVC's during the years 1995 to 2006. The highest total DVC count was in 1996 with 159 DVC's reported (Figure 6). 1996 also accounted for the highest PP's at 86. The UR total was the second highest reported at 73. The most UR's reported was in 1995 with 91. 2003 had the lowest total DVC's reported with 61 (Figure 7).

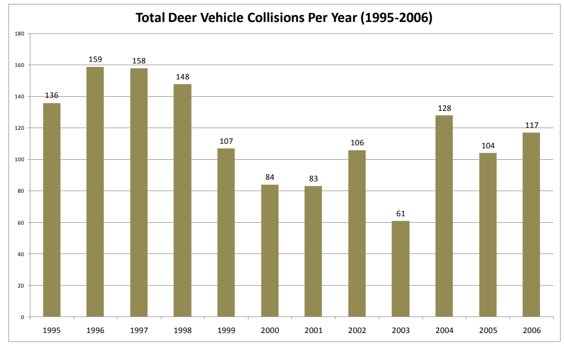

Figure 6. Total DVC's per Year 1995-2006.

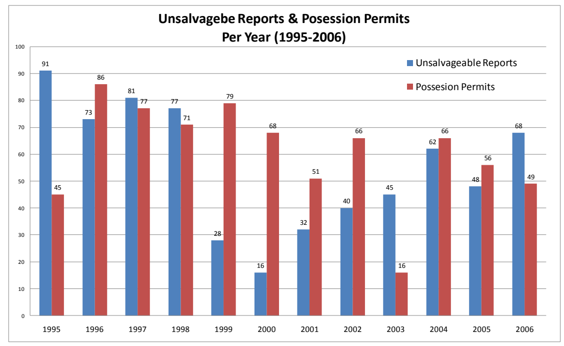

Figure 7. UR's and PP's per year 1995-2006.

White-Tailed Population

After analyzing and comparing Steele County's white-tailed deer population (Figure 8) with the total the DVC's, there were no consistent relationships observed. For example 2003 and 2004 have equal population estimates. However 2003 had a total of 61 DVC's and 2004 had twice as many DVC's reported with 128. Conversely, 2005's deer population estimate was 2,103, which was slightly higher than the 2,070 reported in 2006. 2006 had slightly more DVC's 117 more than the 104 noted in 2005.

Spatial Analysis

The article, Relative Risks of Deer-Vehicle Collisions along Road Types in Southeast Michigan (Sudharsan et al., 2009) found roads with higher speeds and greater traffic volumes and near deer feeding areas to have higher DVC risks.

Steele County's density analysis displayed these higher risks. The possession permit linear results show the majority of DVC's occurring on Interstate 35.

In fact, from 1995 – 2006 Interstate 35 accounted for 72% of the total DVC's in Steele County. Coincidently, Interstate 35's traffic volume was 72% of Steele County's 2006 total traffic volume according to 2006 Trunk Highway Volumes General Highway Map, Steele County by MN DOT (MN DOT, 2006).

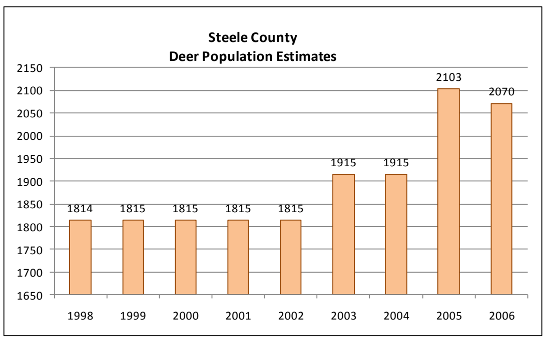

Figure 8. Steele County White-Tailed Deer Population Estimates 1998-2006.

Each unsalvageable report density results from 1995 to 2006 are shown in Figures 10 to 21. The density analysis displays consistently high DVC levels along Interstate 35, especially, in three distinct areas. Figure 9, a DVC density map for the years 1995-2006, clearly shows these three areas.

Most years showed similar patterns to Figure 9 with a few sporadic hotspots. Examples include: 1995 (Figure 10) the year with the highest UR total, 2004 (Figure 19) and 2005 (Figure 20) which were average UR counts, and even in 2000 (Figure 15) which had the lowest UR totals. However, the year 2003 (Figure 18) did not show these major high-level density areas like Figure 9. Instead, 2003 had moderate DVC levels all along Interstate 35. More interesting, 2003's higher levels were in areas that most years had small to no density levels.

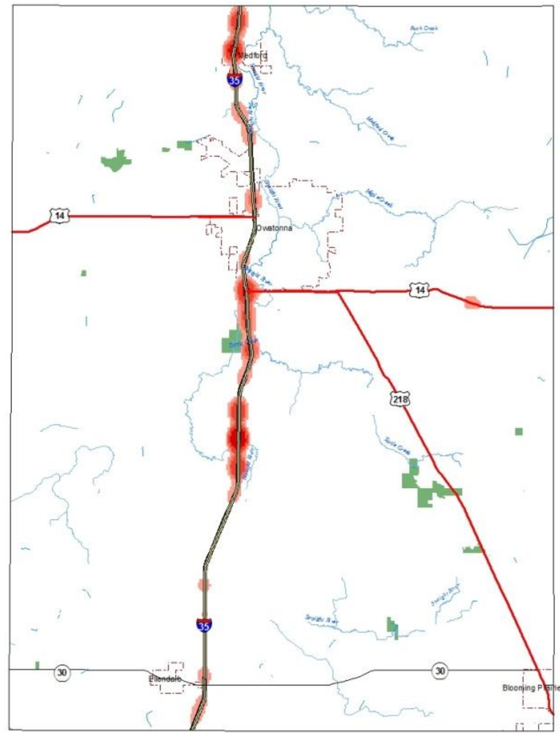

Figure 9. Steele County 1995-2006 Unsalvageable Carcass Density Results.

The area with the highest accident rates was on Interstate 35 between mile markers 35 to 39. The area includes exit 35 rest stop and where the interstate crosses the Straight River. Near mile marker 39 is the Somerset Wildlife Management Area. Also nearby is the confluence of Turtle Creek and the Straight. This area had at least 2 DVC's every year and most years had greater than 5 DVC's.

The other areas containing consistent high DVC density levels were near higher population densities and/or major road intersections. There were consistent high levels of accidents on Interstate 35 near Medford, in the north central part of the county. This area showed high levels each year except for 1999 (Figure 14) and 2001 (Figure 16). However in 1999 and 2001 accident levels were lower throughout the entire county. The intersection of US Highway 14 and Interstate 35 had a large number of DVC

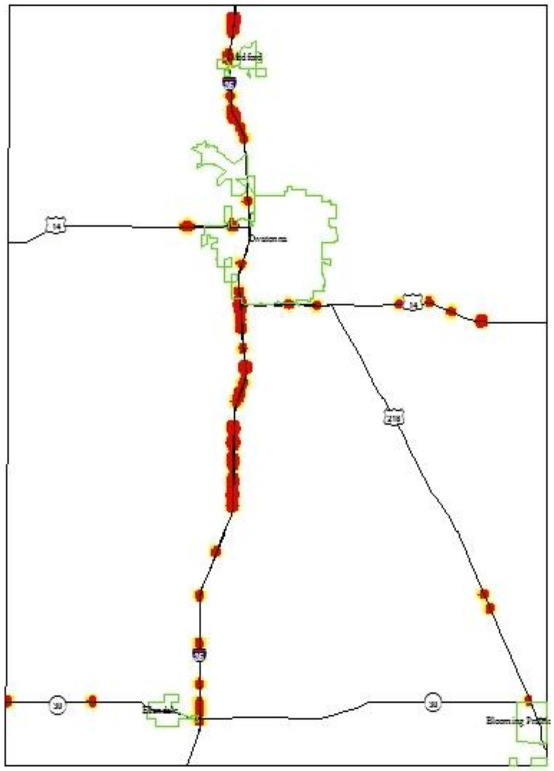

Figure 10. Steele County1995 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

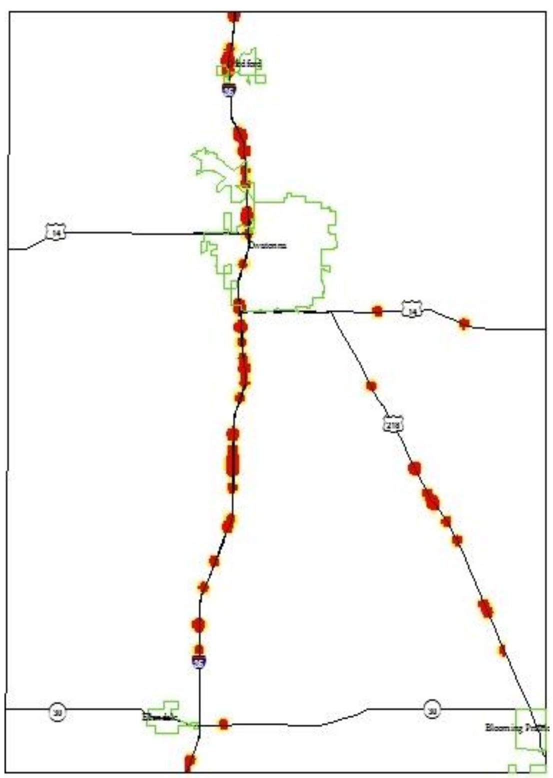

Figure 11. Steele County1996 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

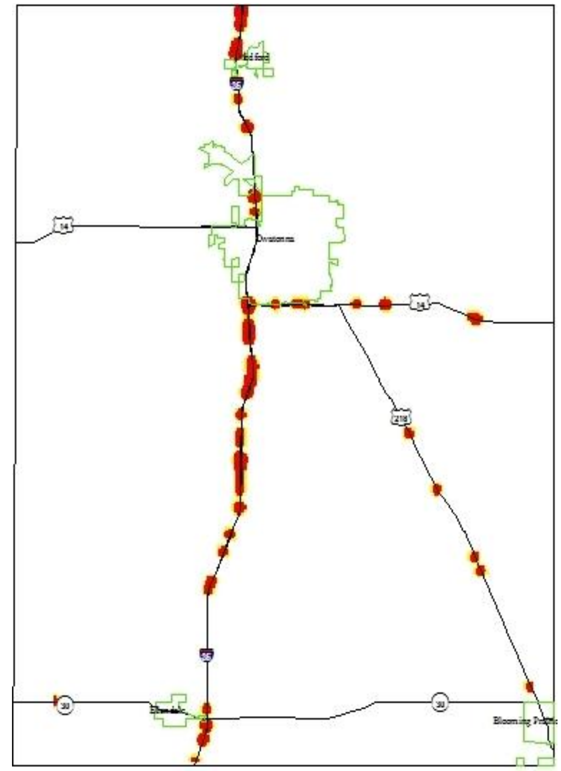

Figure 12. Steele County1997 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

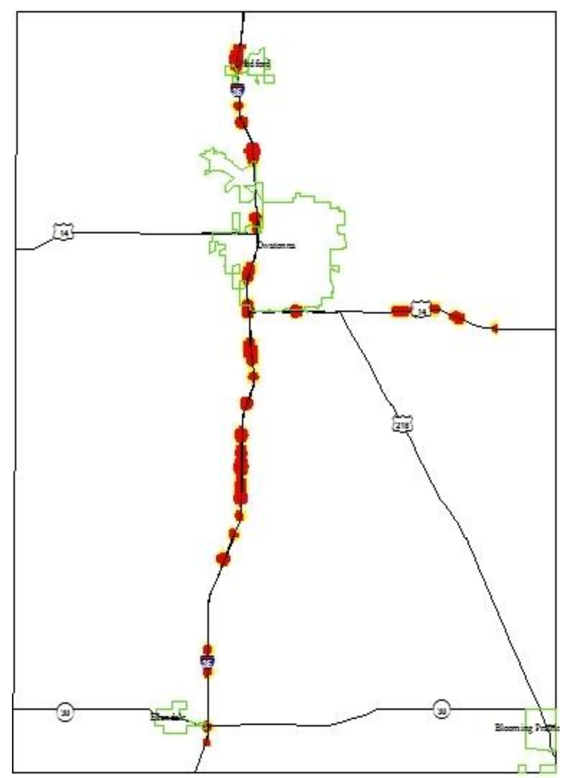

Figure 13. Steele County1998 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

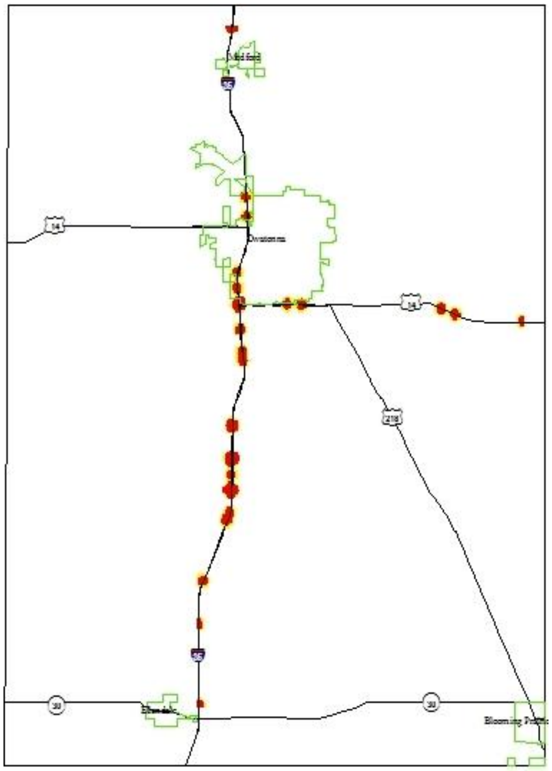

Figure 14. Steele County 1999 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

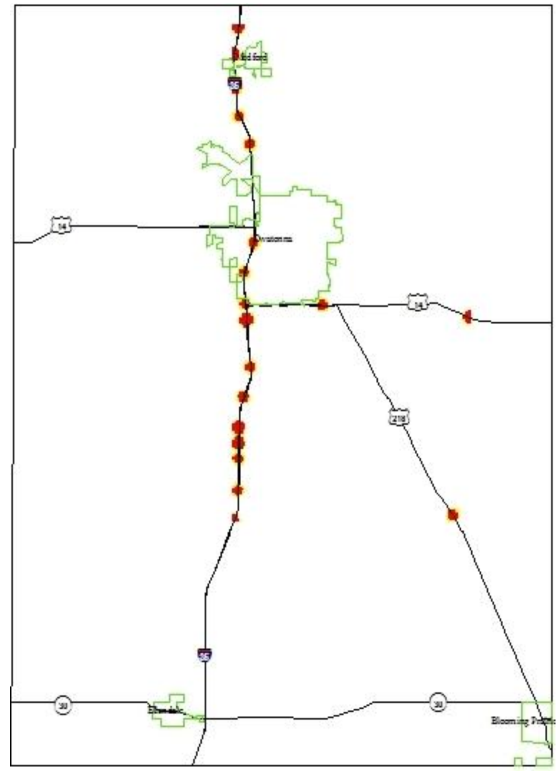

Figure 16. Steele County 2001 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

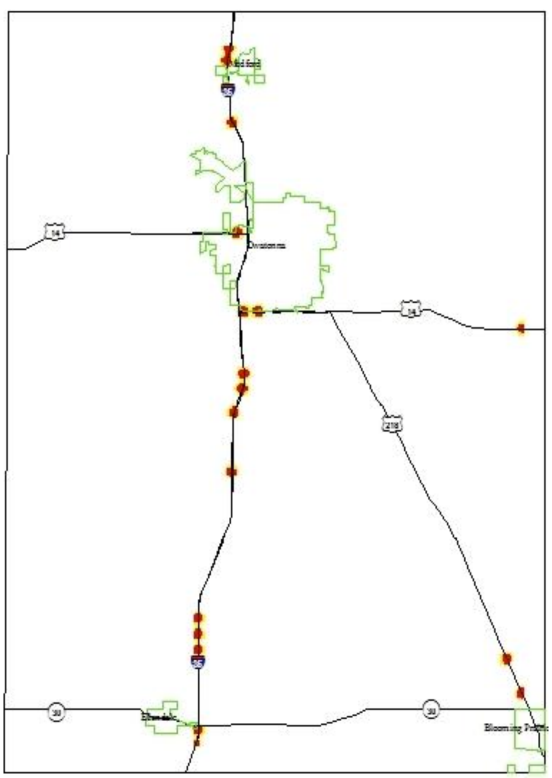

Figure 15. Steele County 2000 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

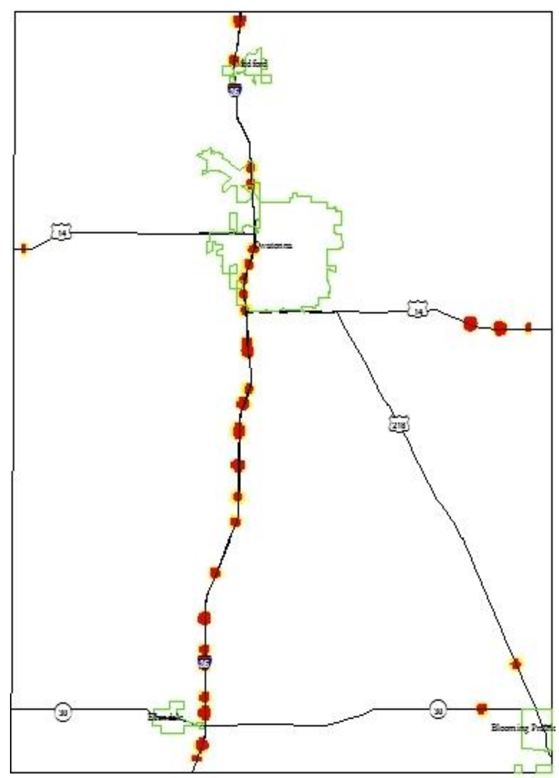

Figure 17. Steele County 2002 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

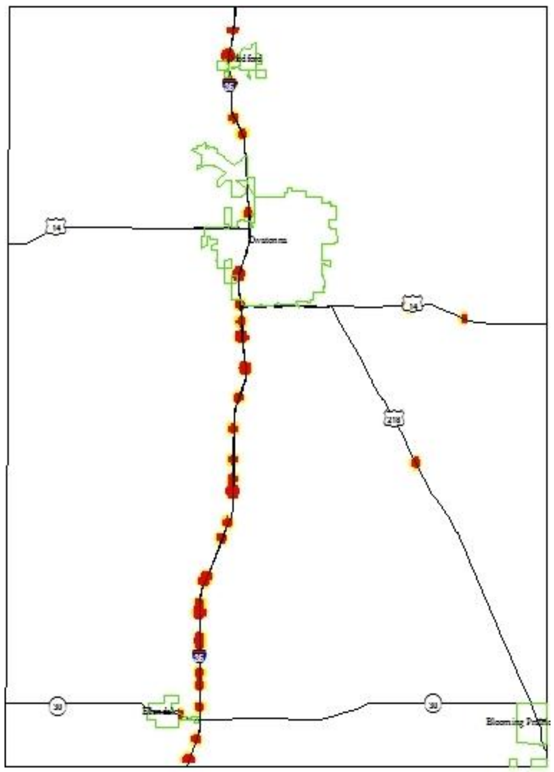

Figure 18. Steele County 2003 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

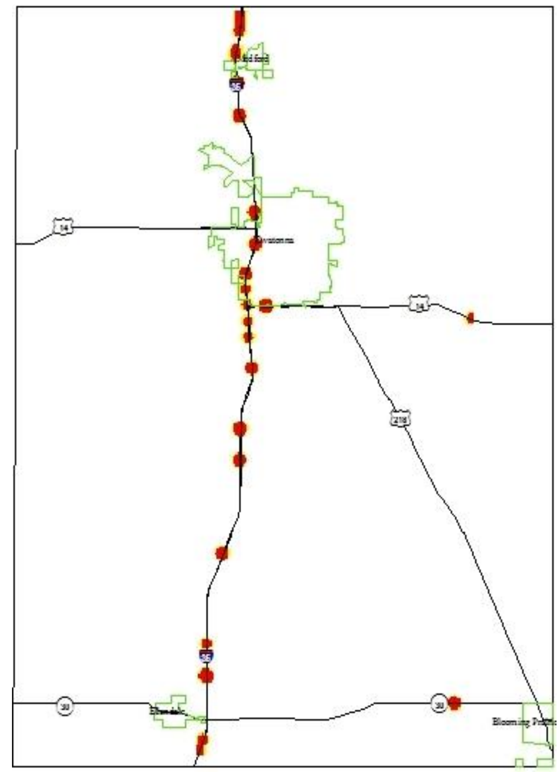

Figure 20. Steele County 2005 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

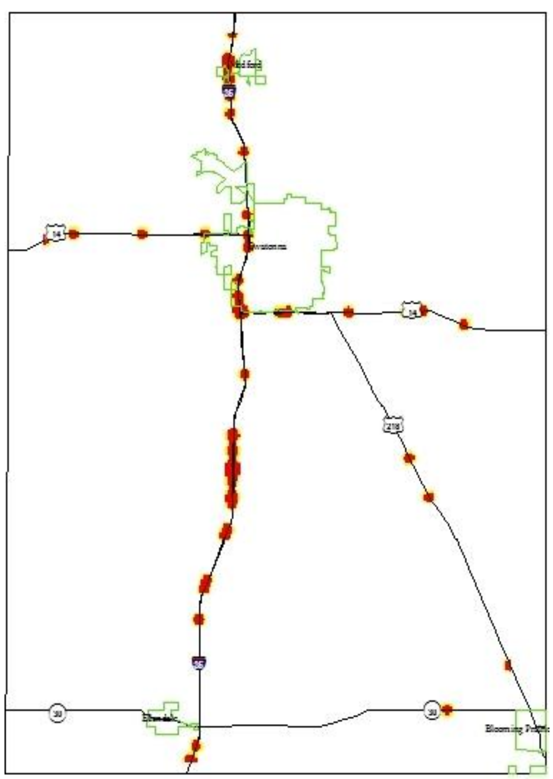

Figure 19. Steele County 2004 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

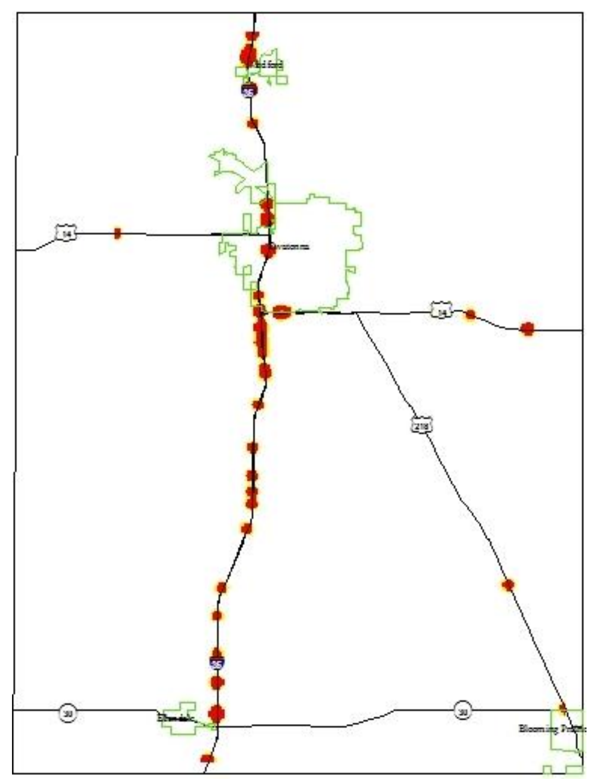

Figure 21. Steele County 2006 Unsalvageable Unclaimed Reported Deer Vehicle Collisions.

occurrences. Not only is this area a major intersection it is also near an urban DVC counts during the breeding season area, the City of Owatonna. Each year this major intersection had high density levels except 2001.

Another area showing moderate to high DVC levels from year to year was at the intersection of Trunk Highway 30 and Interstate 35. The years 1995, 2002, and 2006 (Figure 21) showed higher densities near Highway 30. However this area also had years of few or no DVC's. 2001 had no DVC's in this area and 1996 (Figure 11) and 1999 showed fewer DVC's than other years.

Other major roads did not display consentient DVC density patterns. US Highway 14 displayed moderate DVC levels five miles east of Owatonna in the years 1995, 1998 (Figure 13), 1999, and 2002 (Figure 17). Furthermore, this area reported 2 or more DVC's in all years except 2000. The year 1998 had the largest DVC count for this area. US Highway 218 had low level DVC's and a distinct density pattern. The years 1996 and 1997 (Figure 12) had the highest DVC's on US 218. However, most years showed very low density levels and the years 1999 and 2005 had no DVC's.

White-Tailed Seasonal Patterns

The white-tailed deer seasonal patterns were determined from (Yarnes, 2008), Using GIS to Mitigate Deer-Vehicle Accidents in Winona County, MN. The white-tailed seasons were categorized into three periods. The herding season is the first season which begins January and ends in April. According to Ramakrishnan, Daugherty, Pelkey, and Williams (2005), during the herding season, does and bucks form separate herds. Additionally, many doe are pregnant at this time. The next is the fawning season. This season occurs during the spring and summer months of May through August. The white-tailed buck's are often alone or are in much smaller herds. The doe's home range is much smaller while caring for fawns. Finally, the breeding season runs from September through December. During this period, rutting bucks separate and roam much expanded areas while searching for does and defending their territory.

The highest DVC's reported both in unsalvageable reports and possession permits occurred in November from 1995 to 2006. August was the month with the lowest DVC's reported (Figure 22). Steele County DVC monthly patterns were similar to Winona County totals.

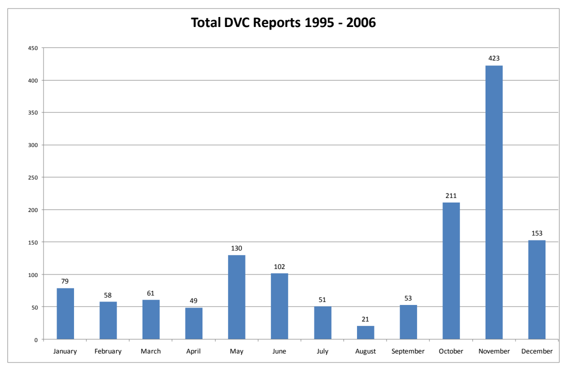

Figure 22. Total DVC's per month (1995-2006).

According to Yarnes (2008), November had the highest DVC totals and August had the lowest. Steele County exhibited the same pattern. An interesting difference was Steele County's second largest DVC count occurred in October while Winona County's occurred during May.

Figure 23 shows separate results for unsalvageable reports and possession permits. Fall to early winter was the period of high occurrences among both types, but possession permits totals are higher during these months. UR's are notably greater than PP's during the months May and June.

The breeding season had the

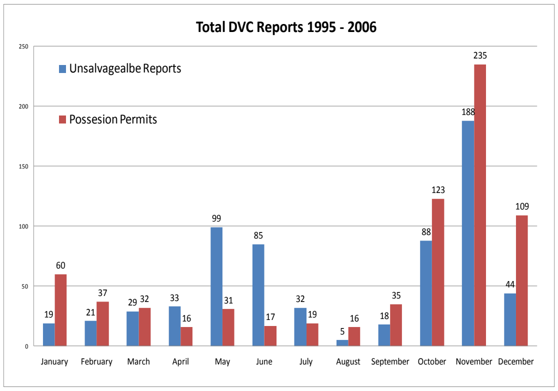

Figure 23. UR's and PP's per month (1996-2006).

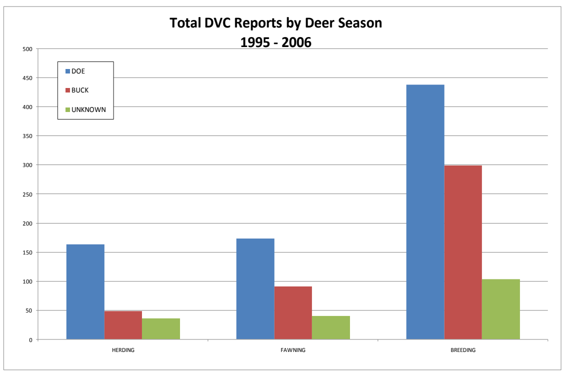

Figure 24. Total DVC's per Breeding Season (1995-2006).

largest number of DVC's from 1995 to 2006 (Figure 24). Each year had higher (Figure 25). An interesting trend for each season, doe are involved in 55% of the reported DVC's while buck account for 31%. Doe account for 52% of the DVC's during the breeding season.

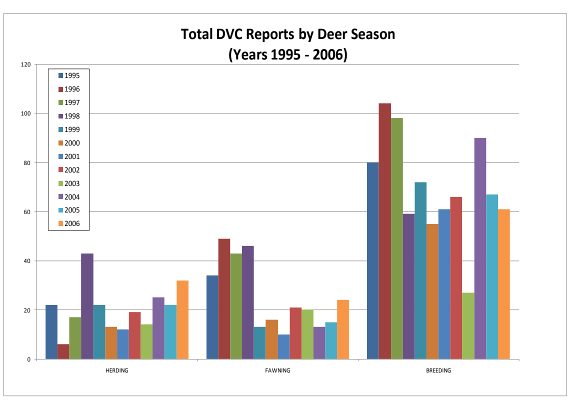

Figure 25. DVC's and Breading Seasons per Year (1995-2006).

Agriculture Seasons

Harvesting was the primary focus for the agricultural analysis. The harvest season was determined using USDA Crop Production Summaries 2003 to 2006. In 2005, the harvest began in October and was 95% completed by mid-November (USDA, 2006). This was similar to 2003. 2003's harvest lasted from the middle October to the middle of November (USDA, 2004). There was a slight difference in 2004 due to wet conditions. According to USDA (2005) findings, the 2004 harvest began in the middle of October through the end of November. Using these findings, October and November were determined to be the major harvesting months.

There is a correlation between corn harvest and DVC's. November accounts for 32% of the possession permits and 28% of the unsalvageable reports. October and November account for 45% of DVC's from 1995-2006.

Discussion

Steele County's DVC spatial analysis clearly shows density patterns throughout the county. Traffic volumes, major road intersections, and higher human popul-lations are major factors affecting DVC occurrences. Highly traveled Interstate 35 showed consistent hot spots across Steele County. There were also high to moderate density levels near urban areas. This is supported in other studies such as County-Level Factors Contributing to Deer-Vehicle Collisions in Arkansas by Farrell and Tappe (2007). Farrell and Tappe reported human population and traffic volume are the major DVC contributing factors at the county level.

Seasonal deer patterns and agricultural seasons also play major roles in DVC occurrences. There is a strong connection between DVC's and the white-tailed deer breeding season. The higher number of DVC's during this time can be attributed to multiple characteristics. The breeding season prompts bucks to increase their range by traveling outside their home range searching for doe. While searching, bucks become less concerned with the dangers within their surroundings. In addition, many white-tailed deer begin exiting prime habitat cover earlier in the day to feed in areas such as agricultural cropland areas.

The crop harvesting period also shows a strong correlation between DVC counts, especially in a primarily agricultural county. During the months of most active harvesting, October and November, DVC were the highest in Steele County. In a county with lower prime habitat acreage and higher agricultural acreage, corn fields provide a safe-haven. However when farmers begin harvesting corn, this refuge rapidly disappears. In a mere month, 90% of corn field cover is gone. So not only are the bucks searching for doe, all white-tailed deer are traveling and seeking alternative cover.

Harvesting season explains the only significant difference between Steele County and Winona County. The monthly DVC totals are relatively similar except for October. One might assume the relative increased DVC count in October in Steele County can be attributed to the decrease in safe cover. Otherwise, throughout the year the DVC monthly totals exhibited similar patterns for both counties.

There are some seasonal differences between unsalvageable report and possession permit totals. PP's are higher during the fall and winter months while UR's are notice-ably higher during the spring months. Assumptions can be made attributing these differences to weather. The fall and winter months have much cooler temperatures which help to preserve the carcass after an accident. During the spring and summer months, warmer temperatures create difficulties preserving the animal. Therefore more DVC's result in unsalvageable or unclaimed carcasses during the warmer months.

Conover et al. (1995) reported only half of DVC's are ever documented. For example, many vehicle collisions will not immediately kill the deer. The deer become injured and continue on its way only to die later. An accident like this is never reported and the deer never found. Situations similar to this create errors in obtaining accurate DVC totals. However the unsalvageable reports and possession permits are credible sources and the most accurate available DVC totals.

Future DVC studies should explore DVC locations relative to known white-tailed deer habitat. Even though habitat was not intensely explored, this study shows land cover and land use play an important role in DVC accident locations. This was demonstrated by the high DVC levels near the Somerset WMA from year to year. However land cover/land use is a factor that needs to be further analyzed.

Surprisingly Steele County's white-tailed population did not specifically determine the number of DVC per year. This may be attributed to the overall low deer population within the county. Also, the year's deer populations were estimates derived from multiple permit areas. In future studies, the relationship between deer population and DVC's could be explored at a larger-scale focusing on more specific areas. In addition, the higher doe DVC's could be compared to the doe to buck ratio in these focus areas.

Conclusions

After analyzing the problem of DVC's in Steele County, Minnesota USA from 1995 to 2006 using ArcGIS, Spatial Analyst, and Model Builder, this study found multiple DVC factors. The greatest factors in this rural county DVC's were human population densities and traffic volume. The study also found that crop harvesting and white-tailed deer patterns have major DVC seasonal affects in this county, a primarily agriculture county.

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