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A Study of the Deer Herd on the RIT Campus and the Relationship of Herd Activity and Habitat to the Incidence of Deer-Vehicle Collisions

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A thesis submitted in partial fulfillment of
the requirement for the degree of
Master of Science

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ABSTRACT

This research project is designed to provide RIT with preliminary information on the possible impacts of campus landscape management and development on the resident deer herd. The project characterizes habitat variables, field observations, and movement patterns, and correlating that information with the incidence of deer-vehicle collisions on the roadways of campus and the surrounding area. The project utilizes geographic information systems (GIS) and remote sensing techniques, coupled with traditional ground-based observations, to estimate the distribution of the deer herd that make use of the RIT property and to establish a database and map of deer trails and high-use "hot spot" habitats. The database also contains records from RIT campus safety and the local police departments concerning the incidences of deer-vehicle collisions, which are geocoded to local street maps in order to compare the distribution of the herd pathways with the locations of the accidents involving deer. The research focuses on the Park Point development, analyzing information prior and during development. By providing baseline data, this project will enable future researchers to conduct pre- and post- construction comparison to deer patterns by analyzing deer responses from the Park Point area to deer responses throughout the RIT Super Block and the surrounding area. If correlations can be established, it may be possible to ultimately derive a comprehensive management strategy for enticing deer away from hotspots and development sites and into areas where collisions with vehicles can be minimized.

INTRODUCTION

Based on an analysis of 1992 and 2001 National Land Cover Data (NLCD) land use land cover images, 362,184 hectares (894,976 acres) of upstate New York land were modified from natural land covers to human land uses during that nine year period (www.nysgis.state.ny.us/gisdata/). For both wildlife management and land use planning, these changes have major implications for human impacts and interactions with the environment. From an ecological perspective, decreasing the amount of available natural habitat for wildlife and placing humans in closer proximity to these habitats potentially increases the frequency of human/wildlife interactions. As humans encroach on what was previously wild, wildlife must either adapt to human land uses or share increasingly limited natural areas if they are to survive.

Developed human land uses and land covers include road networks, mowed and landscaped recreational areas, residential/commercial/industrial complexes and agriculture. Each type of developed area has its own impact on wildlife, but a unifying characteristic is that roads are linked to development (Trombulak and Frissel, 2000). Road networks, for example, serve to fragment landscapes and facilitate development of housing units. In New York, 141,824 miles of roadways have been built in Upstate New York as of 2006, based on street map USA data (ESRI, 2006), resulting in approximately 1,207,305 hectares of land devoted to transportation, assuming an average road width of 40 feet (including right-of-way). This is 9.87 % of New York State's total land area of 12,228,111 hectares (U.S. Census Bureau, 2006). According to Trombulak and Frissell (2000), roads of all kinds lead to seven general ecological effects:

- mortality from road construction,
- mortality from collision with vehicles,
- modification of animal behavior,

- alteration of physical environment,
- alteration of chemical environment,
- spread of exotics, and
- increased use of areas by humans

Deer, particularly the American white-tail (*Odocoileus virginianus*), seem to be exceptionally capable at adapting to human development pressures. Faced with shrinking and fragmented natural habitats in many areas, deer populations across the United States are more often adapting to the developed habitat, rather than relocating to areas far removed from human civilization (Porter, Underwood and Woodard, 2004). Deer are moving into urban and suburban areas instead of the more traditional settings of rural and forested areas. This in turn leads to more frequent human/deer interactions, such as deer-vehicle collisions. The need to develop effective deer management strategies is increasing, since many of the deer's natural predators have been eliminated and deer populations throughout much of the US are rising (DeNicola et al., 2000; Rawinski, 2008; Rooney and Waller, 2003).

In their analysis of the deer populations in Irondequoit, New York, Porter, Underwood and Woodard (2004) document this adaptive behavior and the consequences of human-deer interactions, analyzing movement behavior, dispersal, and the potential need for localized management of deer in a suburban environment. Their study focused on the potential to manage the population of a local deer herd through contraception. Their results suggest that the dispersal rates of the female deer may be critical to the long-term success of the contraception management strategy, but that the main cause of mortality for the female deer in the study was through vehicle collisions. This study illustrates the difficulty of managing deer populations in an altered, human dominated landscape.

In 2008, the human population of the U.S. was also rising overall, but not uniformly. For example, the population of New York State increased 1.5% from April 1, 2000 to July 1, 2005 ((3) United States Census Bureau, 2007), but the population of Monroe County, NY dropped 0.3% over the same time period ((2) United States Census Bureau, 2007). Land use per person in Monroe County, however, had increased as a direct result of the City of Rochester expanding and the tendencies of its population to venture out from the city and into the suburbs (Pendall, 2003). The City of Rochester actually decreased 2.1% in population from April 1, 2000 to July 1, 2003 ((1) United States Census Bureau, 2007), but continued to increase in size due to sprawl. This was a pattern seen in many other areas of the U.S. during that time frame as well.

Management Strategies

These differences in human population and land use growth vs. deer population growth and habitat use are resulting in an increasing problem across the United States involving the incidence of deer-vehicle collisions. As a result, many municipalities are now actively exploring deer management plans. In Akron, Ohio, for example, Summit County chronicled the deer overpopulation issue in regional metro parks (Metro Parks, 2006). Deer-vehicle collisions, increasing deer populations, and the effects of browsing deer necessitated the development of a management plan to control the deer population, including proposals to relocate animals, individual contraception, fencing, and selective planting of ornamental shrubberies. The management plan ultimately chosen by the City of Akron was the use of sharpshooters to cull the herd through the removal of deer by controlled use of firearms by certified individuals (Metro Parks, 2006). This plan of action may not be suitable to many communities or populated areas, such as the Rochester Institute of Technology (RIT) campus, due to public sentiment and/or safety, as well as local regulations concerning the discharge of firearms.

One less invasive management strategy for preventing deer collisions is using signs to warn of the presence of a deer (Al-Ghamdi and Algadhi, 2004). According to Al-Ghamdi and Algadhi (2004), there is a significant speed reduction that occurs as a direct result of the signs. They also indicate that a triangular warning sign with a black silhouette on diamond reflective material proved most effective. Al-Ghamdi and Algadhi (2004) performed a literature review of the use of mirrors and reflectors to deter deer from entering a roadway and found an overall lack of confirmation regarding the effectiveness in these methods. Garrett and Conway (1999) on the other hand believe that the combination of a reduction in speed, lighting of high-use areas, installment of wildlife underpasses and brighter headlights will reduce the incidence of animal-vehicle collisions. VerCauteren et al. (2006) explore the implementation of fences for deterring deer from crossing a roadway. Conn et al. (2001-2002) believe that safe driving habits such as driving sober, within the speed limits and with a safety belt on will assist in the prevention of the occurrence and injury from the incidence of a deer-vehicle collision. As suggested by Garrett and Conway (1999), the most effective method of redirecting animals from using roadways to cross into adjacent areas of wilderness is the installation of both fences and over/underpasses.

As opposed to the more passive means of deer management, Rondeau and Conrad (2003) suggest the use of physical culling of the herd to reduce the overall population and thereby reduce the number of animals that can physically use a given area, let alone cross roadways. Rutberg et al. (2003) even suggest the use of immuno-contraception to control the population of white-tailed deer through a non-violent, yet very invasive methodology.

Developing an RIT Appropriate Management Plan

The Rochester Institute of Technology mimics a small city, with clustered buildings and parking areas surrounded by large, landscaped recreational fields, agricultural fields, and relatively undisturbed natural habitats (forests, wetlands, shrub areas, fields and meadows). It also possesses 13 km of interior roads and 9 km of bounding roads. The large number of deer on campus creates deer management issues not unlike those of the surrounding municipalities. The two square mile area of land upon which the main RIT campus resides was a dairy farm from pre-1931 into the early 1960s, based on analysis of aerial photos and archives (http://www.rit.edu/history.html).

RIT Super Block Land Use in 1930

Figure 1.

This meant that the land was mostly cleared fields with fragmented stands of timber to accommodate the cattle living there as seen in Figures 1 and 2 in 1930 and 1951 respectively. The fields were probably mostly used for growing of hay and grains with some areas left fallow to allow the cattle to graze freely too. It is probable that most of the wooded and fallow areas were primarily wetland areas that were not able to be farmed at that time. These areas grew in size over the years to create a riparian buffer along Red Creek that was used by local wildlife as a travel corridor.


RIT Super Block Land Use in 1951

Figure 2.

The construction of the modern day RIT campus began in 1964 at its present location after the land had been purchased in 1961 (http://www.rit.edu/overview/history.html). In 1968, the arrival of RIT and the management plan for its grounds allowed many of the agricultural fields in the super block to revert back into forests, herbaceous fields, and wetlands, providing abundant deer habitat and increasing the size of travel corridors.

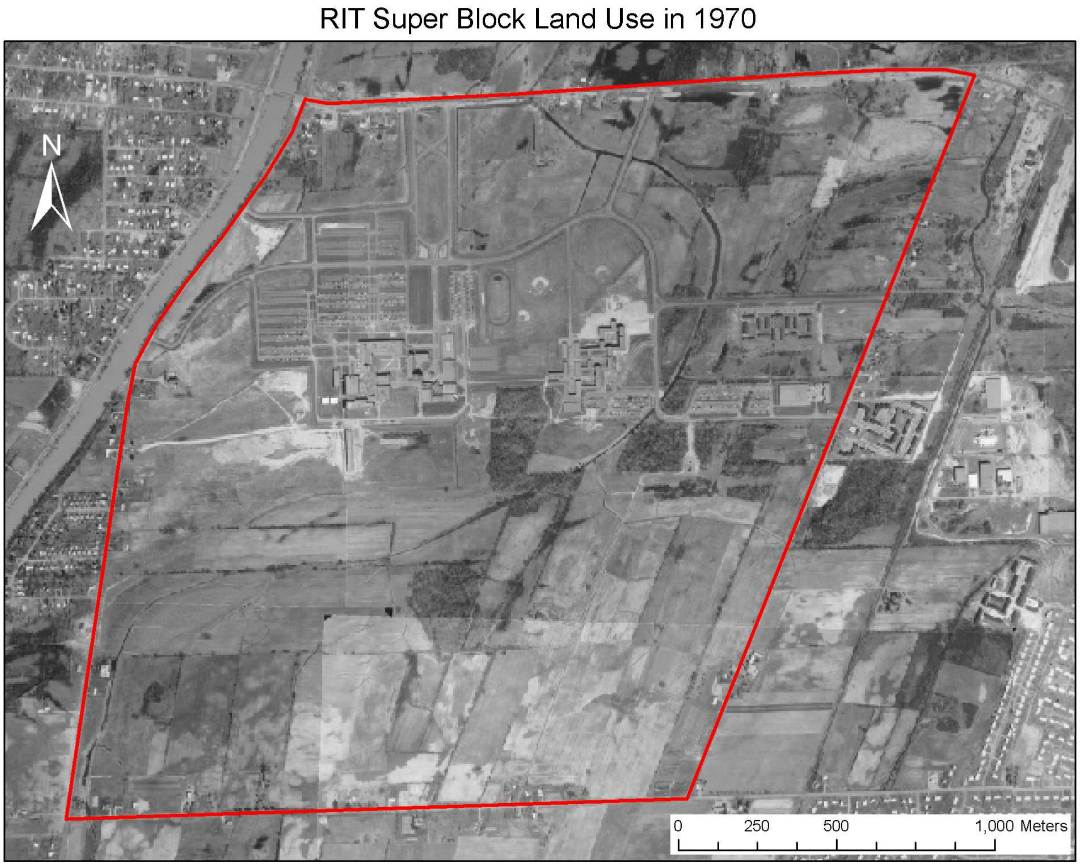


Figure 3.

However, as seen in Figures 3 and 4, this habitat is severely fragmented by the RIT campus infrastructure. In 1999 (Figure 4) we see the RIT Super Block much as it was when this research was conducted in 2007-2008. This timeframe shows the largest riparian buffer along Red Creek, which is a corridor used by the deer to travel from bedding areas in the northeastern part of the campus to the fields in the southern part of the property. Roads significantly fragment the landscape and serve as barriers to wildlife movement throughout the area.

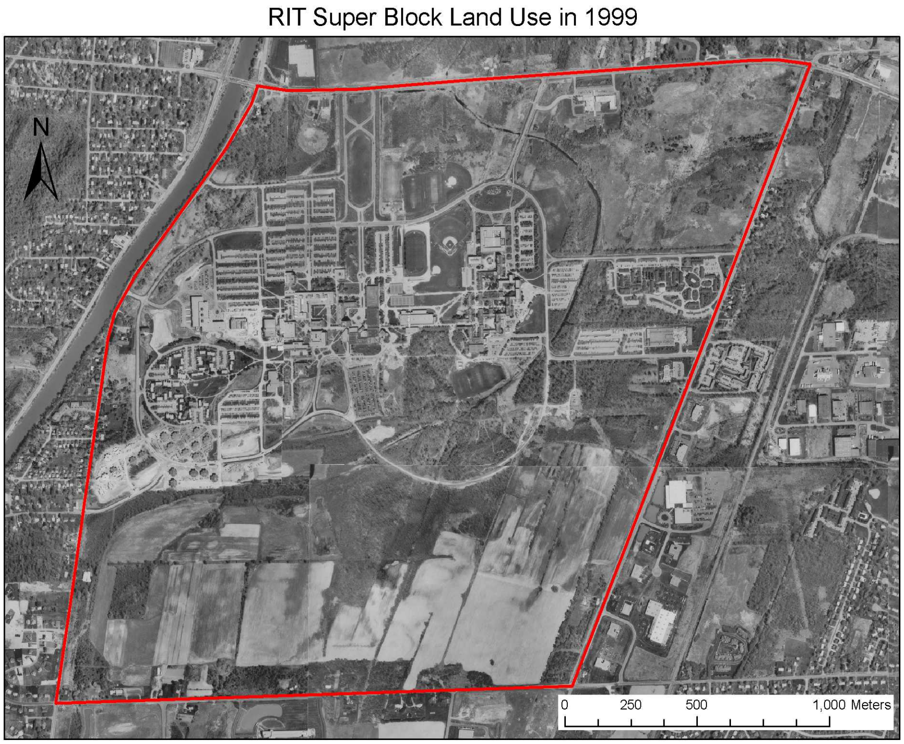


Figure 4.

As RIT expands the campus and begins to develop more of these natural areas, human-deer interactions are likely to increase. In 2008 there were ongoing developments in the areas within the land surrounded by John Street, Jefferson Road, Perkins, Lowenthal and East Memorial Drives known as the Park Point project (Figure 5). These developments were replacing existing forest,

Figure 5.

field, and wetland habitats with commercial and residential areas, roads and parking, and ornamental land covers. Traffic flow was also expected to increase. The development provided a unique opportunity to document the before-and-after comparison of the activities of the local deer herd to the landscape alteration. One ecological concern of RIT was the displacement of deer from the Park Point area and the potential for increased deer-vehicle collisions.

The purpose of this study was to conduct a pilot project to develop a baseline deer movement database related to deer habitat and deer vehicle collisions; evaluate different management strategies; and propose initial RIT management strategies and develop additional, follow-up analyses. There are several elements to accomplish the objectives of this study. The first element is to establish a baseline assessment of deer activities on campus and will allow future researchers to determine changes in deer behavior as a result of campus developments, such as Park Point. To accomplish this, deer trails on campus will need to be characterized to determine where deer trails intersect with roadways in and around the RIT campus. These will be correlated with deer-vehicle accident data to help determine hot spots potentially needing protective measures. Second, evaluate remote sensing approaches for detecting deer as a viable approach to determining a population estimate. Third, create a land cover database. All three of these analyses will be used to recommend deer management strategies and may be the first steps in creating a campus natural resource management strategy.

MATERIALS AND METHODS

Trails

Deer trails with entrances intersecting RIT roads and county roads surrounding the RIT superblock were mapped using a GPS to identify potential collision areas and to link to the deer strike database. The RIT Super Block consists of bounding roadways Jefferson Road, John Street, Bailey Road and East River Road and all roadways encompassed by these (Figure 4). A trail entrance was defined as a disturbance in the natural presence of vegetation / environment consistent with the edges of a roadway. Common indicators of a trail included trampled vegetation, upturned soil, and the presence of deer tracks in soft earth. These are some of the visual indicators commonly used to classify deer trail systems in a quantitative manner. Figures 6 and 7 attempt to show classic visual examples of heavy and light use trail systems (respectively) through photography.

To qualitatively classify the deer trails found during this study, a classification scheme was developed, inspired by the Strahler Stream Order Classification Method. Essentially, a heavy use trail was defined by following a trail from its head (the point at which a trail left the side of a roadway and led further into the forest/open field) until it came to a point where an intersection was observed with at least one more deer trail. At this point it was deduced whether the trail followed was converging into a single main trail system or diverging into smaller, less traveled trails. If the trail being followed did diverge into smaller trails, it was deemed a heavy use trail. The logic behind this stemmed from the fact that a trail that is created from the joining of two or more smaller trails would be traveled more frequently than a trail that was created from splitting off of a major pathway.

Figure 6.

A light use trail was defined as a pathway that converged into a single heavy use trail as one moved further from the roadway of interest. This concept was generated in an attempt to take some of the subjectivity out of trail classification systems that only use quantitative indicators.

Figure 7.

Only heavy and light use trails were defined for the purposes of this study. Medium use trails may later be defined using more subjective factors including the presence of scat, trampling of the area, and trail width but were omitted for brevity of the overall study.

Trails around the campus were inventoried by walking along the roadways of interest (those roadways encompassing the RIT Super Block as well as interior roadways) with a Garmin Venture GPS logging each individual trail head that was encountered much like Kissel and Tappe (2004) used a GPS to identify target locations in their study. To map the deer trails, the GPS was used to create track logs and mark waypoints at intersections. These data were then transferred from the GPS to a computer using a program called DNRGRAMIN, freeware developed by the Minnesota Department of Natural Resources (DNR) (MN DNR, 2006), and saved in shapefile format for use with a geographic information system (ArcGIS version 9.2).

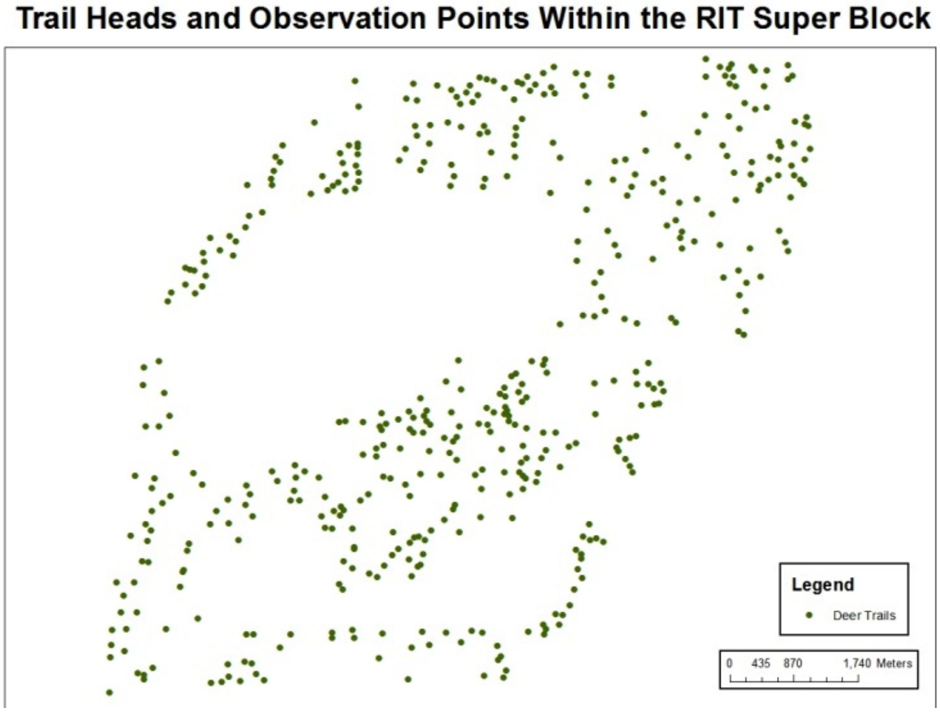


Figure 8.

Once the waypoints and tracks were downloaded and associated with the appropriate projected coordinate system, as seen in Figure 8 (in this case UTM Zone 18, NAD83), the trail shapefiles were overlaid onto a map of the area to view such characteristics as distribution, frequency, and overall number of trails within the area of interest. The trail classifications were assigned to each individual trail by the previously proposed classification scheme. Trails were also cleaned up in the ArcMap editor to remove any noise in the track data (Figure 19).

The resulting database was then displayed upon georeferenced aerial color photographs of the area in a way that displayed both the intensity of use of any given trail as well as the approximate location along a given roadway. The heavy use trail heads were depicted as red squares, the access road trail heads were depicted as blue triangles, and the light use trail heads became green circles (Figure 18). This final result will be used to help look for correlations between trail data and the other data sets associated with this project.

Collision Data

Annual counts of deer-vehicle collisions (DVCs) on the RIT campus and the surrounding roadways were obtained from the RIT Public Safety department beginning in 2000 (the date to which the oldest record extended). The records collected contained the date, time, and location of the incident, and any details that were recorded by the responding officer.

Next, the Monroe County Sheriff's Office was contacted to obtain records from their database regarding local DVCs. The database acquired from them consisted of records dating back to 1993 concerning DVCs on Jefferson Road, Bailey Road, John Street, and East River Road, as well as the roads encompassed by the RIT Super Block. This database contained information such as the date, time, roadway, nearest cross road, and case number (which was disregarded).

These two datasets were broken down by location, month and time of day in order to look for trends, such as a heightened number of DVCs at a certain time of day, certain time of year, or in a specific location. The statistics associated with the location of a given DVC were entered into a geospatial database created using ArcMap v9.2. To create this DVC database, it was necessary to digitize road segments on the georeferenced images of the RIT Super Block, identified by a unique number. DVC table data were then joined to the road segments using the unique ID. DVCs were thematically displayed by road segment using the same logic employed for the trail data. Instead of treating each DVC as an individual event, they were grouped together based upon the road segment that best represented the location of the incident. This information was then displayed as a line segment with a thematic intensity representative of the number of DVCs that had occurred along a given road segment (Figure 15).

The dates were further grouped by month in order to assess any seasonal trends in the DVCs. Actual weather data were not included in this analysis, so it is assumed that over the period of record, monthly weather patterns were close to long term monthly averages (temperature extremes and precipitation amounts). Future studies may wish to include weather data to refine the seasonal analysis.

The DVCs were assigned to a time of day attribute representing dusk, dawn or other; and upon AM vs. PM records in the DVC data. While AM vs. PM generalizes the data, it was necessary to retain a statistically valid sample size on an annual basis. This methodology negates the effects associated with sunrise and sunset, which are heavily associated with animal movement according to many sources (Al-Ghamdi and Algadhi, 2004; Biggs et al., 2004; Garrett and Conway, 1999; Haikonen and Summala, 2001). The time associated with sunset and sunrise is highly variable due to daylight savings as well as the nature of the orbit of the planet Earth about the Sun.

Observations

In addition to recorded deer strike data and mapping deer trails, deer behavior on campus was also observed to attempt to distinguish additional correlations, such as the size of the deer groups, distance of the groups from the roads, preferred browsing spots or vegetation types, and behavior in the presence of people and vehicles. Observations took place using two very distinct techniques: personal observations in the field and a participatory survey involving RIT commuters, public safety officers, and the grounds crew.

The first method employed in this study was personal observations. The primary routine used for personal observations involved traveling along the study roadways, primarily by bicycle. Observations were also done from a car and while walking or running. Data recorded included the number of deer seen, sex, relative age, time, and location on a daily basis during the summer months and when possible during the school year. The daily movements of a whitetail deer are irregular in nature - dependent on factors such as weather, predation, season, food supplies, etc. To account for this, consecutive days of observations involved changing the direction in which the roads were traveled. This information was recorded on paper and then transferred to a computer-based database for further analysis.

In addition to mobile observations, a more passive approach was undertaken that involved the use of several ground blinds and tree stand setups for undetected observation of deer in their natural settings. Locations for the installment of an observation point were derived by analyzing trail data as well as the area of interest. Most of the observations took place within the area now referred to as “Park Point”, a new housing and retail development. This was an area of relatively undisturbed vegetation that served as habitat for the local deer herd. The focus on this area in the 2006-2008 research period stemmed from the fact that it was to be developed into an apartment/retail complex (completed in 2008), and the RIT administration was interested in a before and after study. Where multiple trails converged with reasonable visibility, a potential observation point was recorded on the GIS map. After potential sites were identified, the best options were used as actual observation areas. Observations were recorded much the same as when traveling the road network, however a camera and binoculars were employed as well for ease of identification and image documentation.

To address the limitations of a single observer trying to document a widespread deer population, a simple data form was created and provided to members of the RIT grounds crew and campus safety patrols. Both groups travel around RIT multiple times per day, allowing for multiple opportunities to observe deer behavior. The surveys consisted of a map of the campus and several basic questions, including: date; time; location of the sighting; number of deer per sighting; age/sex of the deer seen; and surrounding vegetation. The map helped provide a more accurate location of a deer. Completed surveys were collected from a tray outside of the campus safety office and the data were entered into the GIS database. See Appendix I for an example survey form.

To increase the observation sample size, it was decided to create an on-line version of the survey to allow RIT commuters help expand the database. The original paper survey was recreated as a web-based form with an interactive interface. The map was redesigned to allow for easy identification of road segments (query mode) and use of land features for designation of sighting location. An additional field, comments, was added to allow participants to expand on the detail of their sightings. An e-mail with a link to the survey was sent out to all RIT faculty members in spring quarter of 2007 and to the College of Science faculty members in the spring quarter of 2008.

The data collected from observations were analyzed both qualitatively and quantitatively depending upon its nature. Qualitative analysis was used for the Comments section of the survey-based observations, since the comments were in response to an open ended question. The responses were all read and given a certain category into which they could be grouped for further applicable analysis. Of these respondents 31% responded explaining the location of the deer in relation to the area in which they saw it; 28% responded regarding the activity in which the deer was partaking, whether that be crossing the road, browsing, etc.; 16% gave a response that was of no real value to the study; 5 % gave a description of the area in which they saw the deer, and; 20% gave additional details that may not have been particularly about the sighting but helped to give further context overall. Several outstanding responses were noted for use as examples and/or standalone conclusions.

Quantitative analysis was used for all of the numeric data gathered through the course of this study in addition to fixed response questions from the surveys. The statistics include deer-vehicle collision data, dates, times, locations, surroundings parameters and sex/age information that was recorded as well as the actual observed numbers of deer submitted with each survey. These results are mostly exhibited as thematic counts on road segments through maps created using ArcGIS 9.2. The remaining information will be presented in graphical format in Graphs 1 through 8.

Hyperspectral Imagery Analysis

High resolution hyperspectral imagery was used in an attempt to determine an approximate campus-wide deer population at a single point in time using spectral signature matching (Shaw and Burke, 2003). In order to begin this portion of the analysis it was pertinent to obtain imagery from which to attempt to detect individual targets. This imagery was acquired thanks to those in charge of the WASP (Wildfire Airborne Sensor Program) imagery library at RIT (Special thanks to Harvey Rhody and Don McKeown). Several mosaics of the RIT Super Block were located and stored for further spectral analysis. The imagery collected from the WASP sensor included longwave infrared, midwave infrared, shortwave infrared, and visible (RGB) imagery forming a co-registered multispectral image data set. Airborne imagery is a common source of data for wildlife studies (Martin, 2011; Kissell and Tappe, 2004).

Next MODTRAN (MODerate TRANsmissivity algorithm for atmospheric compensation) was run specifically for the Rochester, New York area. The atmospheric transmission and path upwelled radiance data obtained from the atmospheric compensation algorithm was then combined with the spectral reflectance data taken of several background material samples that were collected in the field using an Analytic Spectral Device (ASD) (http://www.asdi.com/applications/remote-sensing/ground-truthing) to account for atmospheric attenuation, which is an affect commonly seen in remote sensing data (Griffin and Burke, 2003). Atmospheric attenuation is a term used to account for the difference in recorded intensities between remotely sensed data and laboratory measurements due to the scattering of energy by atmospheric particles. Deer hair was collected from hunter harvested and DVC specimens.

The spectral comparison process was conducted manually through Microsoft Excel using deer hair spectra and all background spectra that were collected using the ASD. The reflectance specific spectral signature of the winter coat of a whitetail deer, from 350nm to 2500nm, was compared to fifteen background samples including: soil, leaf litter, tree bark, and vine spectral samples. Differences in spectral response greater than ten percent were considered significant. Ten percent was used to account for the additional reduction in signal that will occur once atmospheric attenuation is applied and because some of the background spectra collected, such as maple bark, did not register differences significantly above that value. This information was then plotted on a graph (Figure 20) in order to be able to easily determine spectral areas in which it would be possible to detect a deer in its natural habitat using remote sensing techniques. After the comparison was completed it was necessary to add in the results of the MODTRAN session to account for atmospheric attenuation of the spectral signatures. The end result of the comparison was used to define optimal spectral windows for identification of deer using an MSI aerial imaging platform (specifically WASP) and to identify special filters for use by the WASP imaging system.

Land Use Analysis

Land use analysis is critical to this study as a variable used to help explain the collision trends and identify potential deer-vehicle collision hot-spots as the campus landscape changes with development and ecological restoration efforts. Land use was determined through the help of maps and figures made available through RIT's Facilities Management Service. These maps, Figures 9 through 12, depict wetland delineation, vegetation parameters, the locations of structures, and the presence of different slopes throughout the RIT Super Block.

Land use allocations throughout the RIT Super Block are seen in Figure 9. Deer will typically use the agricultural fields for feeding and the woodlands and wetlands for feeding/sleeping/travel corridors. At RIT the deer do go into the human populated areas. They primarily feed on the shrubbery planted for landscaping and manicured grass. This map can help to determine prime bedding and feeding locations of resident deer as well as potential travel corridors where deer/vehicle interactions may occur at higher rates. This figure and those that follow were created preconstruction of the RIT Park Point project.

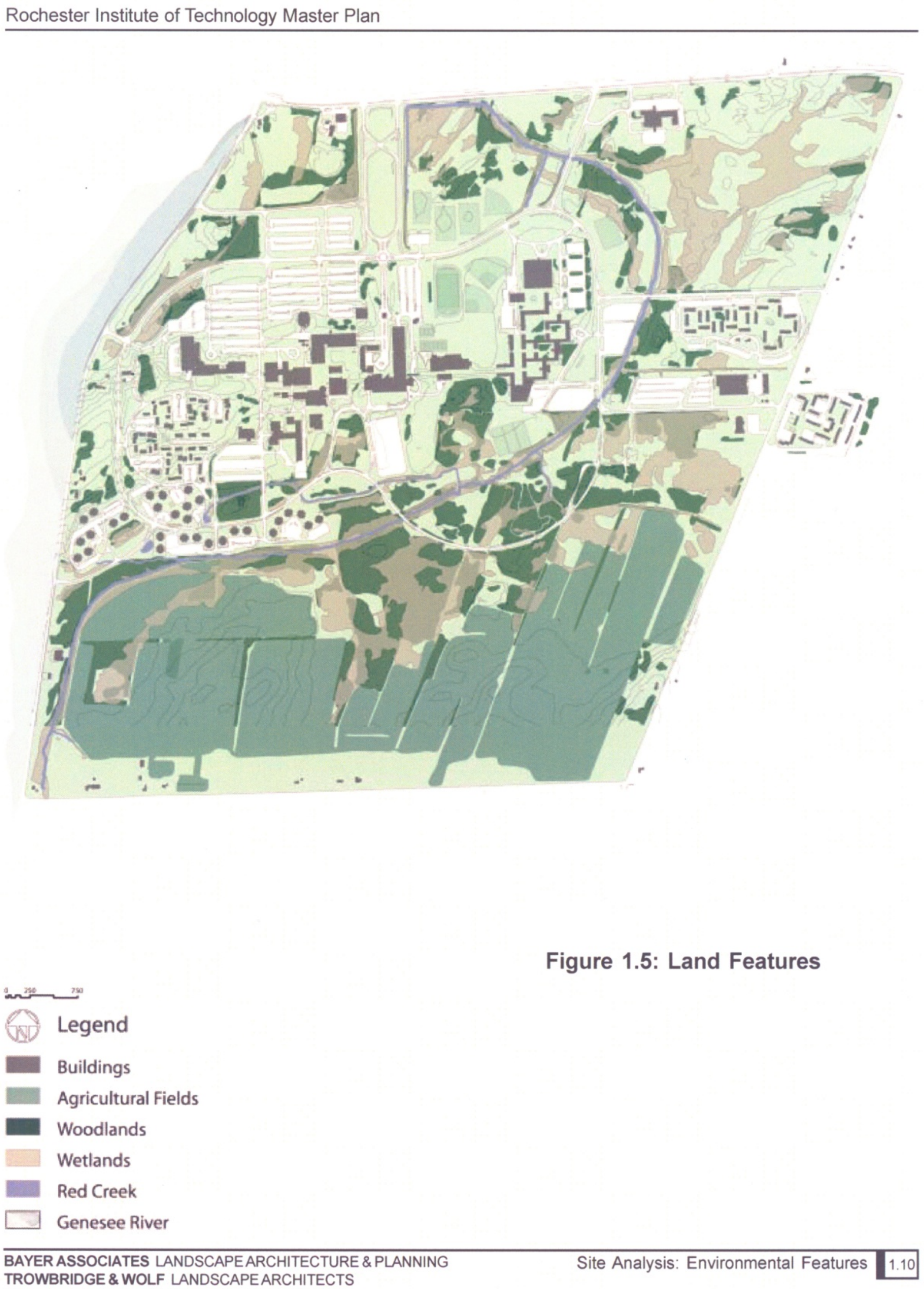


Figure 9.

The approximate locations of wetlands and water sources on the RIT Super Block are shown in Figure 10. This figure outlines areas that will only be used for travel/browsing activity (the wetlands) as well as where the deer can find water. Unfortunately, there are so many water sources here that the deer may not have specific travel corridors tied to them. Also of note here: the Genesee River is directly to the west of campus across East River Road which also provides a major water source for the campus deer population.

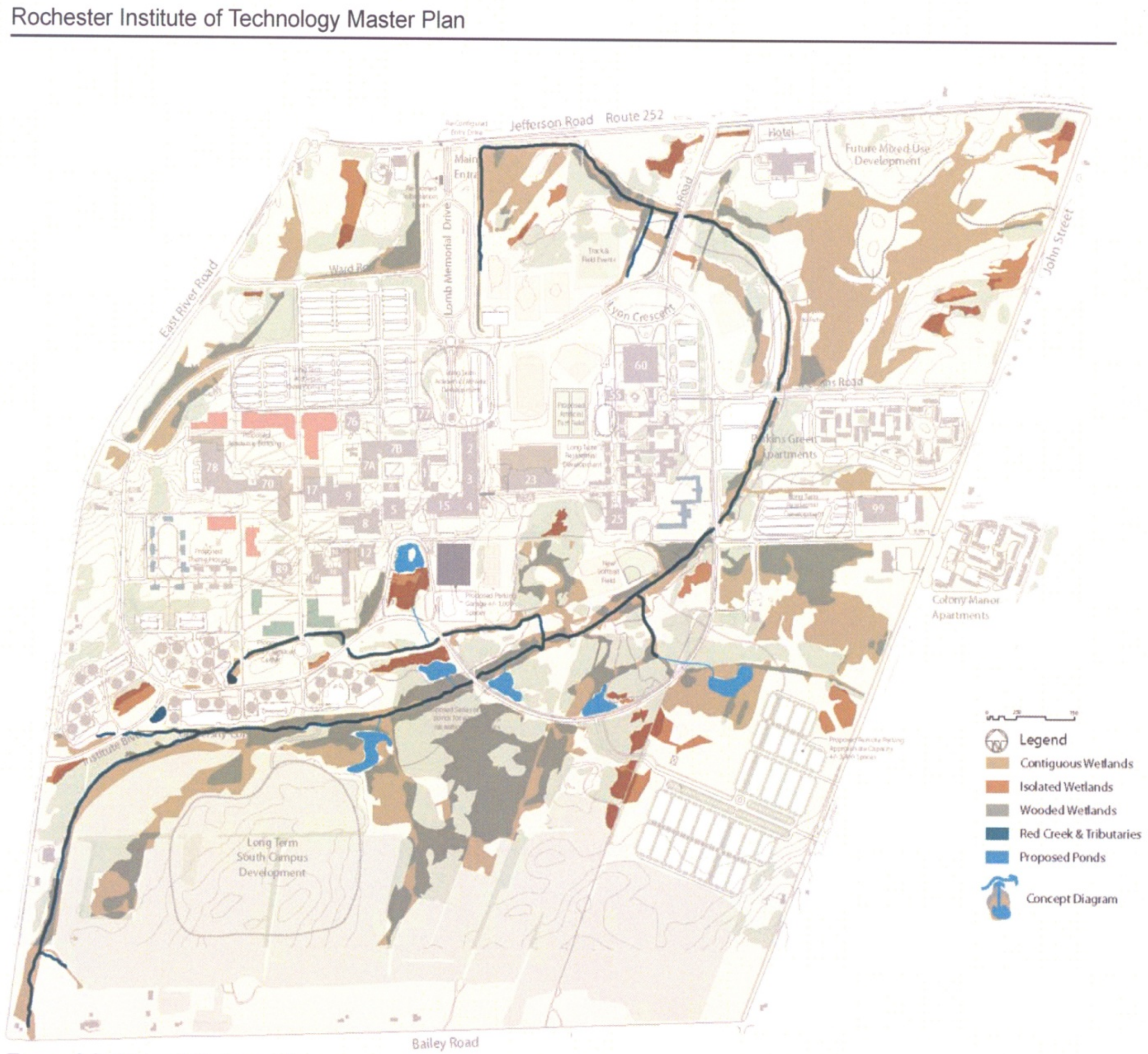
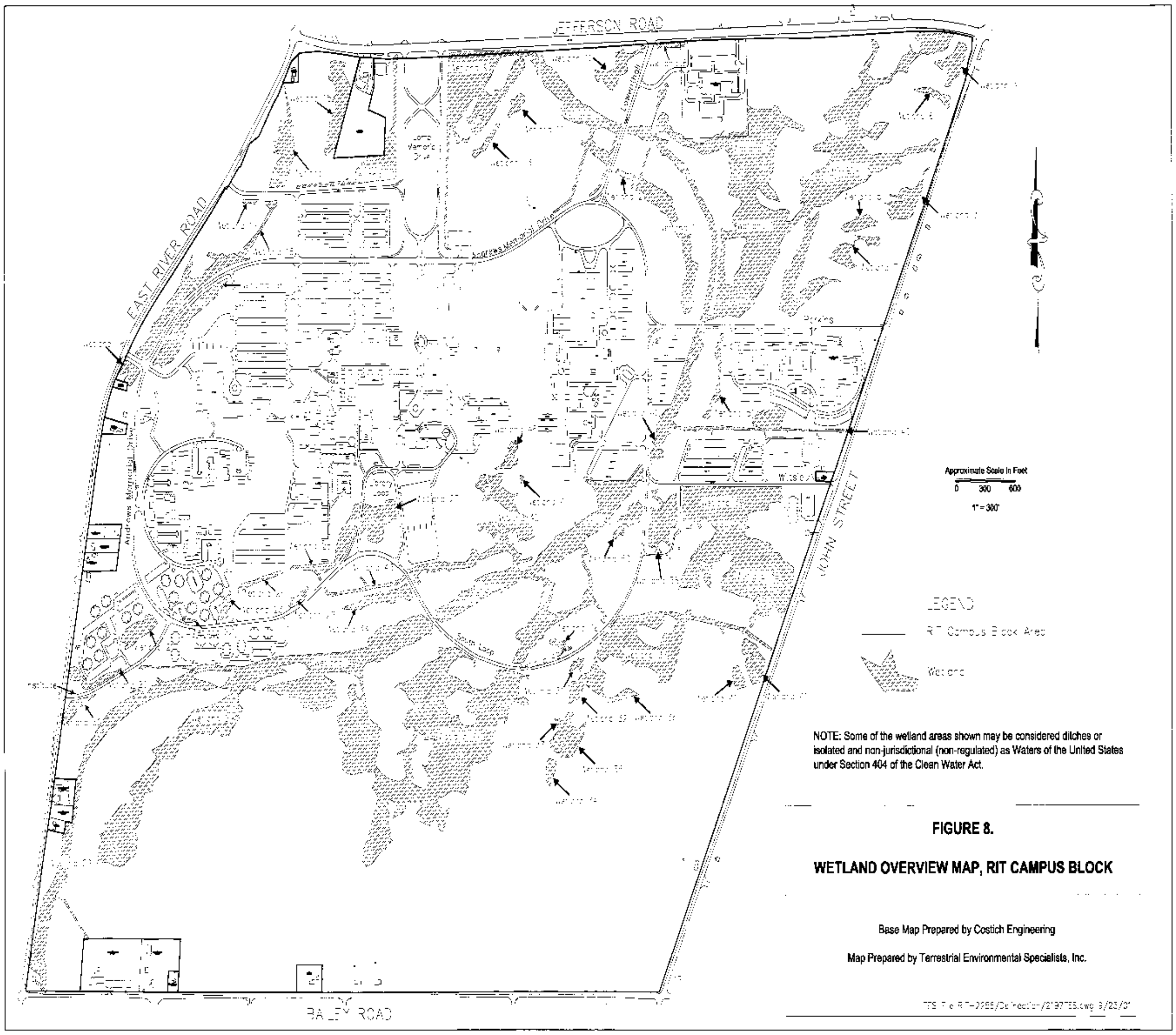


Figure 3.2: Natural Systems Plan

Figure 10.

The information in Figure 11 echoes that from Figure 10, but gives the bare footprint of the wetlands on the Super block without the detail regarding classifications. This information could be used as a mask and combined with elevation and woodland data to help determine likely bedding areas for the resident deer population.



NOTE: Some of the wetland areas shown may be considered ditches or isolated and non-jurisdictional (non-regulated) as Waters of the United States under Section 404 of the Clean Water Act.

FIGURE 8.

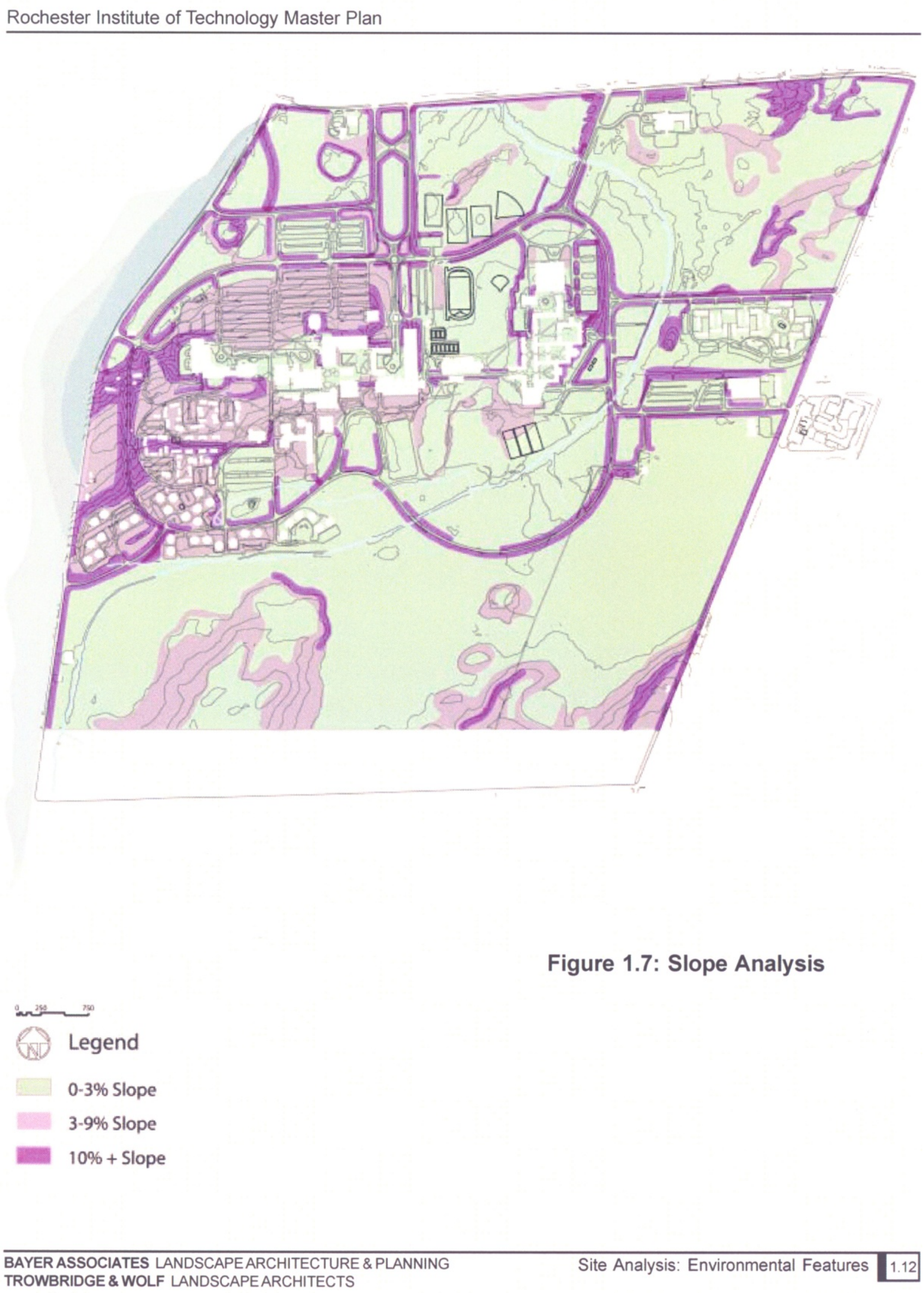
WETLAND OVERVIEW MAP, RIT CAMPUS BLOCK

Base Map Prepared by Costich Engineering

Map Prepared by Terrestrial Environmental Specialists, Inc.

Figure 11.

The elevation change information in Figure 12 would probably be more useful as a topographic map; however we can still use it to find areas of higher ground that could be used by the resident deer for bedding areas. Because none of the areas of 10%+ elevation change are large, they probably won't be of significant influence on deer travel patterns.



Rochester Institute of Technology Master Plan

Figure 1.7: Slope Analysis

Legend

- 🟩 0-3% Slope
- ▨ 3-9% Slope
- ■ 10% + Slope

BAYER ASSOCIATES LANDSCAPE ARCHITECTURE & PLANNING
TROWBRIDGE & WOLF LANDSCAPE ARCHITECTS

Site Analysis: Environmental Features 1.12

Figure 12.

These factors may influence deer movements around campus. If favorable situations in land use match up with favorable situations in regard to other constraints being allocated for in this study, then a potential deer-vehicle collision hot-spot may be identified.

In order to supplement the approach employed above, LANDSAT imagery was downloaded from the USGS website (http://www.usgs.gov/pubprod/). The classification algorithm applied to a 2001 LULC image created by the US Geological Survey as part of the National Land Cover Database is a modified Anderson Level 2 and is based on Landsat images from 2004-5. This is a very coarse classification algorithm, seen in Figure 13, which is used to classify land uses in many different climates and regions. Landsat spectral imagery has 30 meter resolution. Once downloaded, the imagery can be classified and compared to national land cover databases (1992, 2001, 2006) for accuracy assessment.

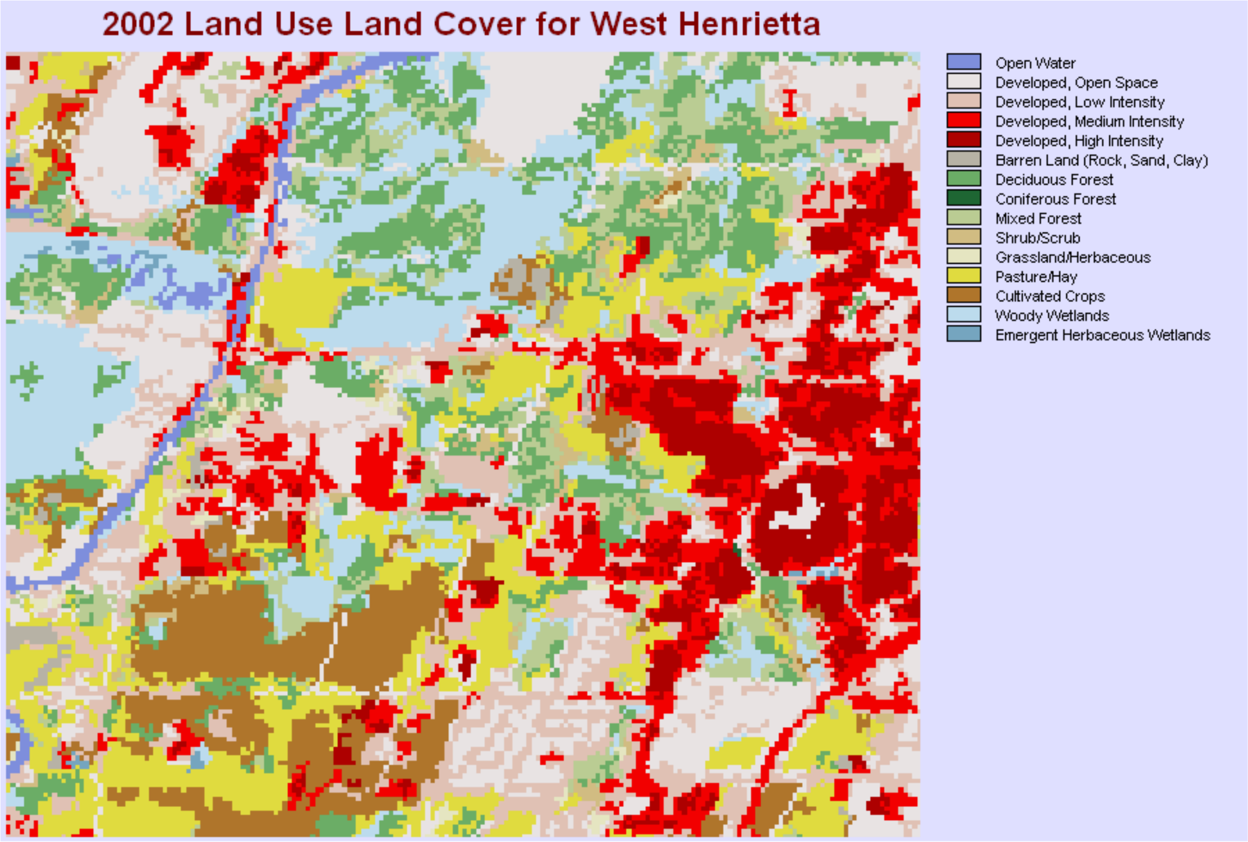


Figure 13.

Imagery downloaded from the USGS site consisted of seven bands and was analyzed using supervised and unsupervised classification algorithms in IDRISI Kilimanjaro (Clark Labs Clark University, 2003). The resulting image will produce a more specific land cover map with regard to wetlands on campus (a known issue with the national maps) and more detail than the generalized campus maps (which focus primarily on the built environment and wetlands). This analysis will contribute to the identification of potential DVC hotspots (Figure 14).

The final step in this element of analysis involves the synthesis of all of the collected imagery and looking for any patterns and/or correlations that may be evident. One method that is effective for this approach to analysis is a cross-tabular overlay. The cross-tabular overlay helps to highlight any areas in which more than one image has a positive or favorable factor over the same general area. Any areas that have more than one factor highlighted may be considered as a potential deer-vehicle collision hot-spot depending on how many factors are highlighted. Due to time constraints this portion of the analysis was not completed, but would be beneficial to subsequent studies.

RESULTS AND DISCUSSION

Land Use Analysis

A land use land cover analysis was conducted to create a land use map that was less generic than the Landsat classification provided by the USGS in Figure 13. A Maximum Likelihood classifier algorithm was used in a supervised classification process to create Figure 14. This classification method involved the use of 125 eigenvalues to determine significant breaks in spectral response to group pixel values based on similarity. A knowledge of the area and the use of aerial photos assisted in assigning pixels to the appropriate 15 land use classes.

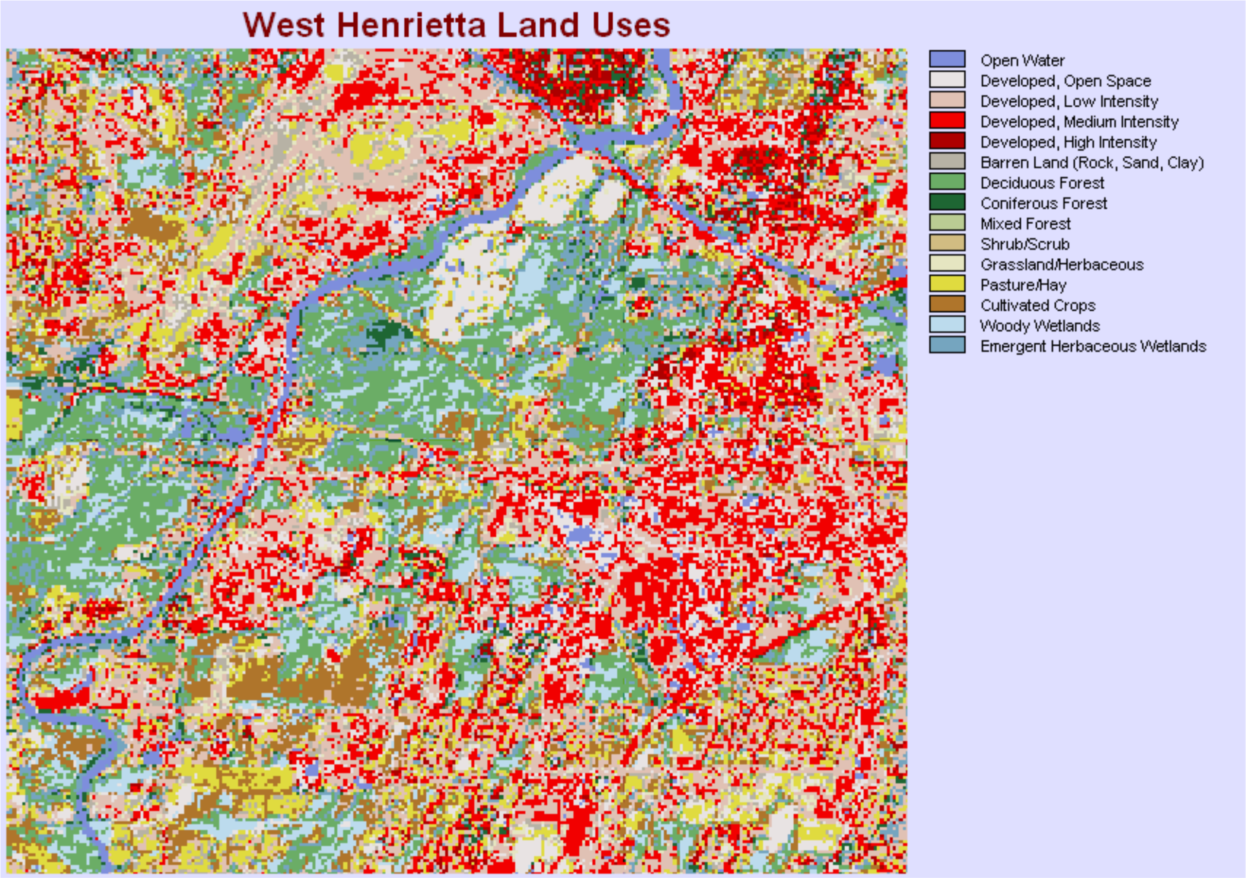


Figure 14.

Figure 14 shows a more specific representation of the land use land classifications in the Henrietta, New York area immediately surrounding RIT. Most of the areas associated with high volumes of deer-vehicle collisions around and within the RIT Super Block are associated with deciduous and mixed forest and shrub/scrub land uses. Deer typically use these areas as habitat and travel corridors. These areas are also notorious for being low visibility environments and therefore afford less reaction time for motorists. By pairing this information with the deer trail data and DVC records RIT can focus a natural resource management plan on areas of heightened risk for DVCs.

Deer-Vehicle Collisions

The most deer-vehicle collisions occurred at the corner of John Street and Jefferson Road, on Jefferson Road between East River Road and Lomb Memorial Drive, and along the eastern and western sections of Bailey Road between 1993 and 2007 (Figure 15).

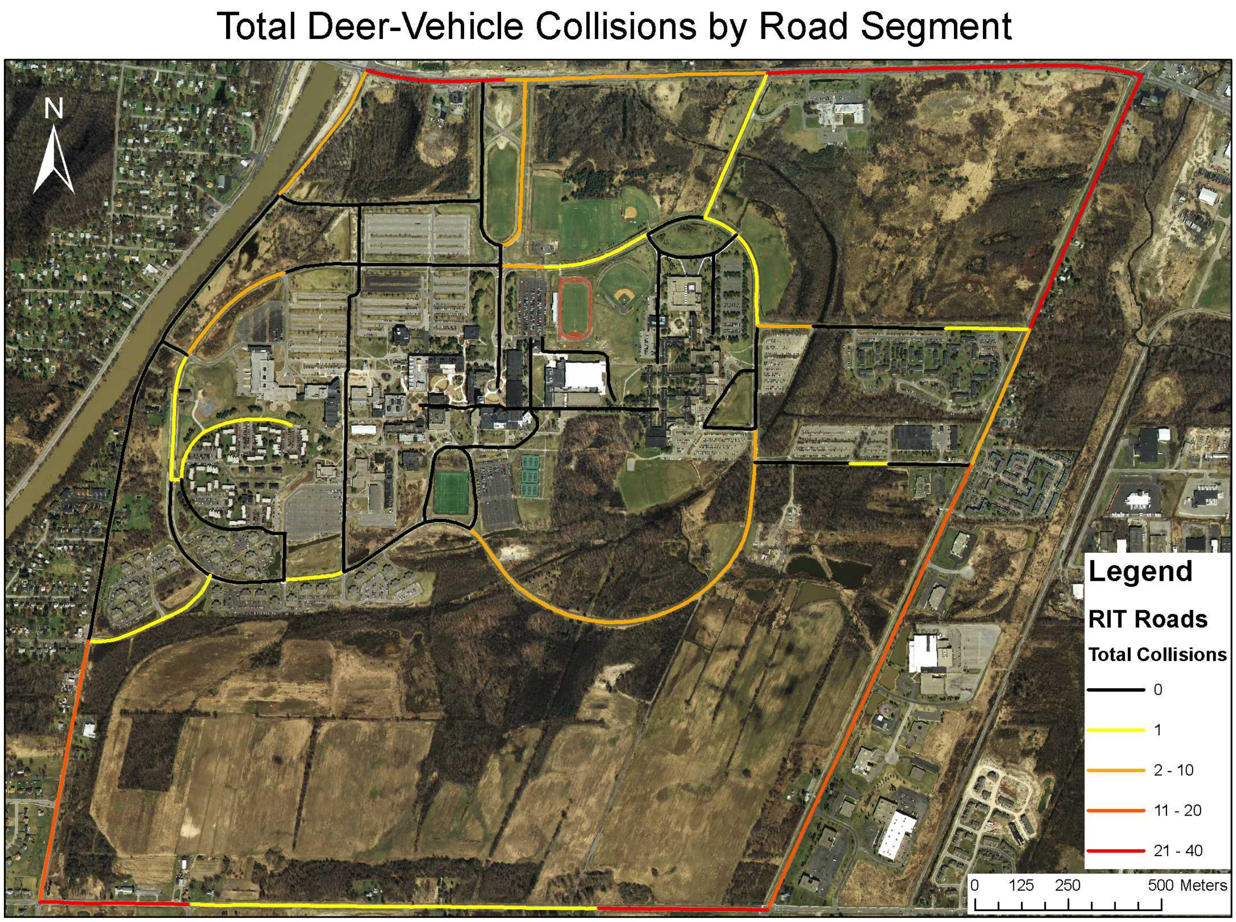


Figure 15.

More DVCs occurred at the corner of John Street and Jefferson Road per year than any other road section around or within the Super Block (Figure 16). Interesting observations in both Figures 15 and 16 include the association between DVC occurrence intensity, developed versus undeveloped landscapes, and the distance between designated stops on the roadways.

The bounding roadways of the Super Block all show higher DVC rates than the roads within the study area. These areas generally have higher speed limits, which create less reaction time and may result in a higher DVC rate in areas of reduced visibility.

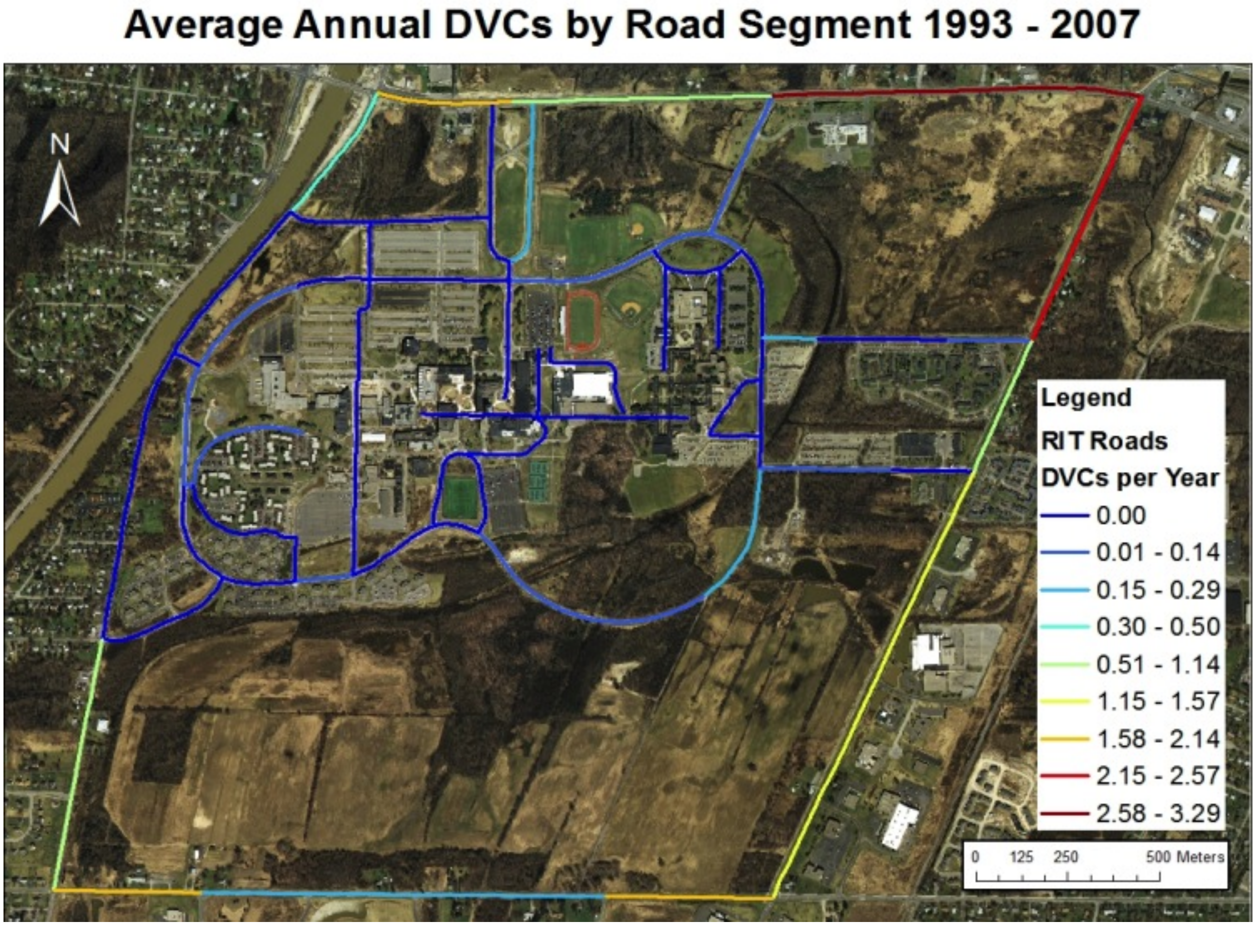


Figure 16.

The corner of John Street and Jefferson Road has the highest average annual DVC rate. A follow-up analysis regarding DVCs around the Super Block would show how the construction of Park Point affected deer movements in the area and whether the current amount of DVCs associated with that corner of the campus continue or if they are redistributed to other roadway sections.

The fourteen year trend at this intersection (Figure 17) reveals no change or a slight reduction in the number of recorded DVCs between the two seven year timeframes (1993-2000 and 2000-2007). Road segments that showed an increase in the number of DVCs were: John Street from

Perkins to Bailey Road; Jefferson Road from Lowenthal to East River Road; along East River Road from Jefferson Road to Ward; and along the eastern section of Bailey Road. The interior roadways of the Super Block were not able to be analyzed for trends because records did not exist prior to the year 2000.

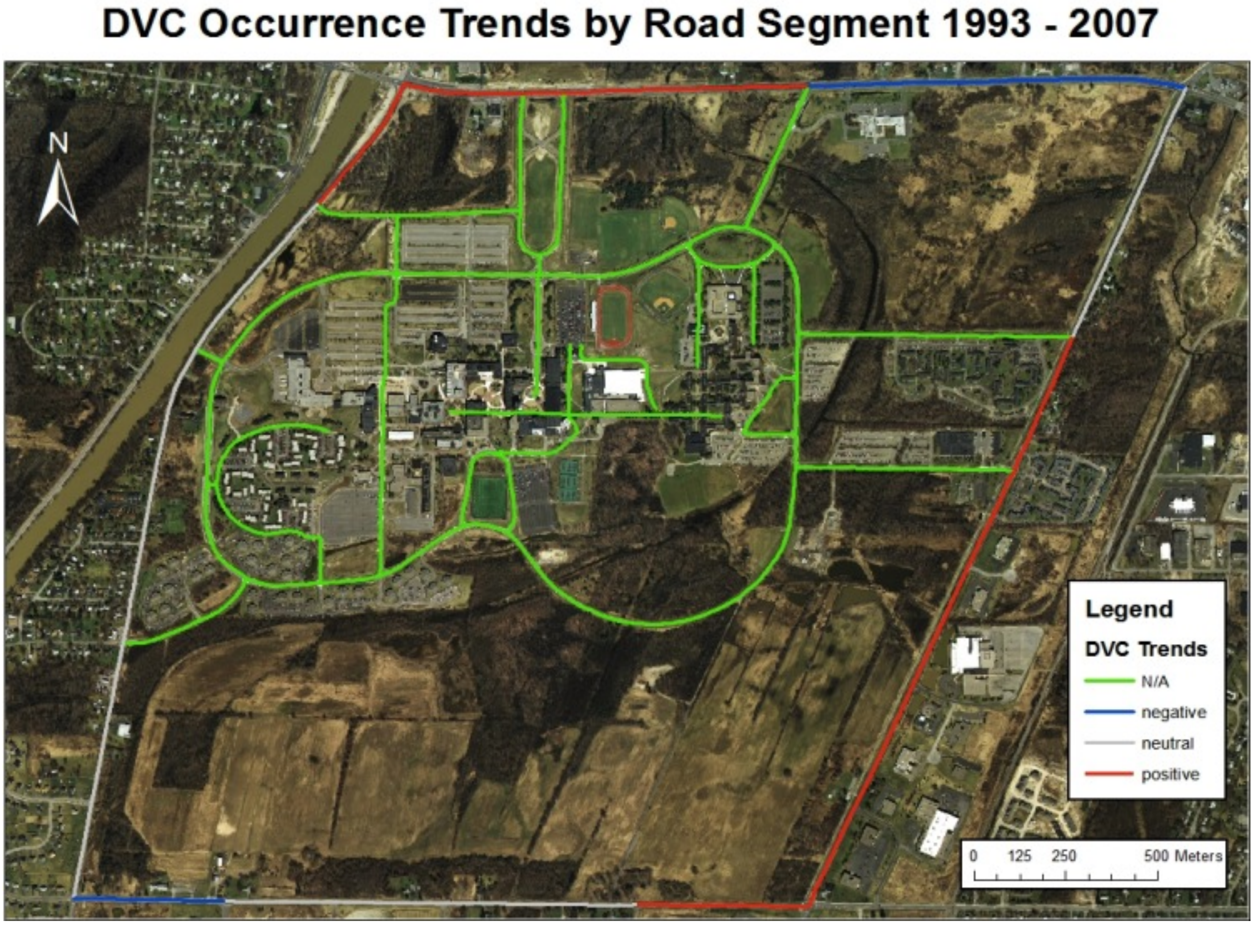
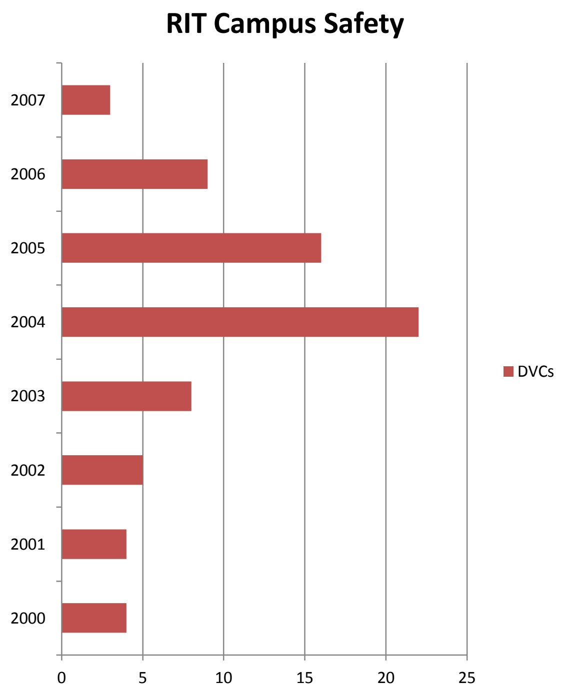


Figure 17.

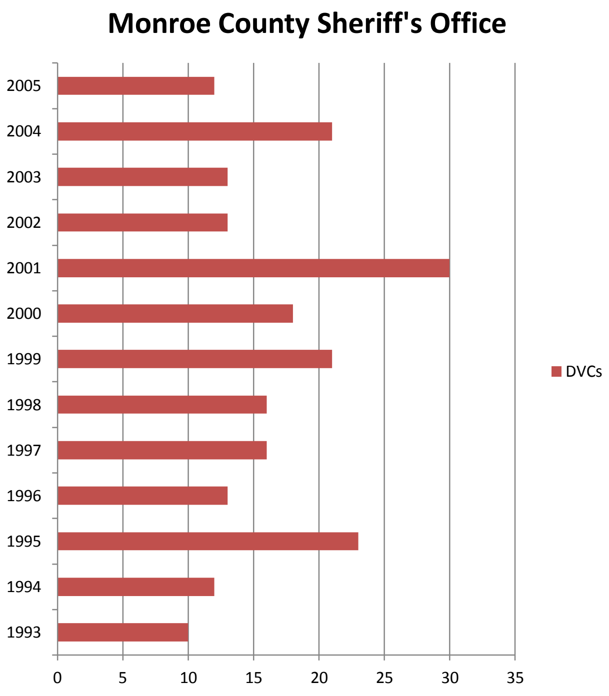
Areas of increasing DVC occurrences show where RIT should have concentrated its attention for a natural resource management plan circa 2008. A follow-up study would show whether the trends from 1993 through 2007 continue despite the construction of Park Point or if new areas need to be identified for proactive measures to address increased DVC occurrences.

More than twenty deer-vehicle collisions were recorded on the roadways around and within the RIT Super Block in 1995, 1999, 2001 and 2004. Overall, there were 289 recorded DVCs on the bounding and interior roads of the RIT Super Block between 1993 and 2007. This information was broken down by road segment to create Figures 16 and 17; and is broken down by year, month, and time of day in Graphs 1 through 8.

DVCs by Year



Graph 1



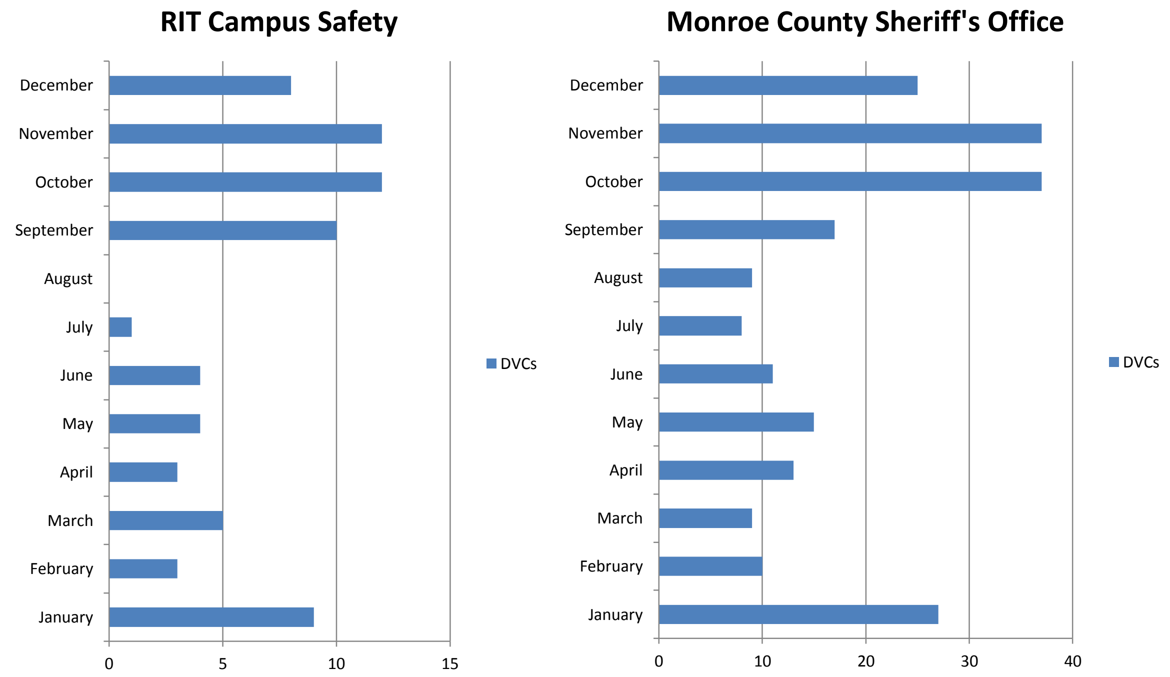
Graph 2

Graphs 1 and 2.

The most DVCs occurred during the months October and November (Graphs 3 and 4). This timeframe is associated with the breeding season for the white-tailed deer (Ransom, 1966). Other months associated with heightened DVCs were September, December, January, April, and

May. Fawns are born approximately 200 days after mating, during the spring of the year (Verme, 1969). The increased numbers of DVCs during these time periods may show a correlation between these times of activity in the white-tailed deer's reproductive cycle and the occurrence of DVCs.

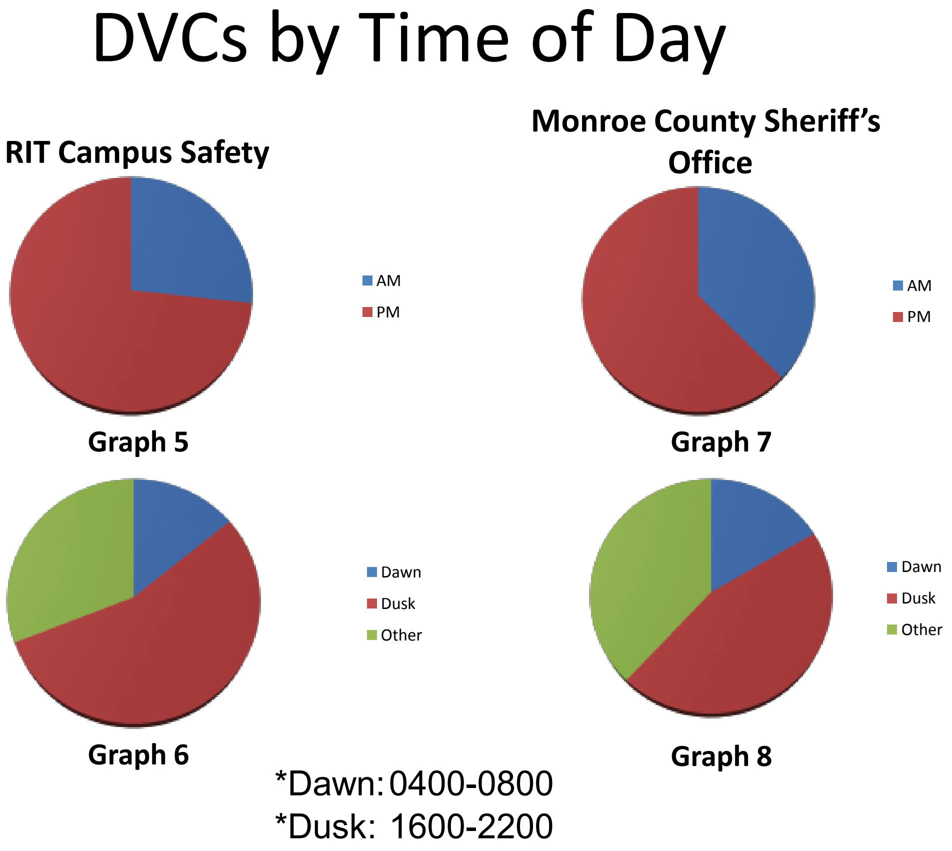
DVCs by Month



Graph 3 **Graph 4**

Graphs 3 and 4.

The results in Graphs 5 through 8 echoed the fact that low-light conditions are associated with the most DVCs (Al-Ghamdi and Algadhi, 2004; Biggs et al., 2004; Garrett and Conway, 1999; Haikonen and Summala, 2001).



Graphs 5 through 8.

In Graphs 7 and 8 the Monroe County Sheriff's Office data (MCSO) shows 62 percent of the DVCs recorded occurred during the PM hours of the day and 66 percent of the RIT Campus Safety DVCs in Graphs 5 and 6 occurred during the same timeframe. The MCSO data shows that 45 percent of the recorded DVCs occurred during dusk hours alone as did 53 percent of the RIT Campus Safety DVCs. When taking into account all of the DVCs that occur during low-light conditions, both dusk and dawn, 62 percent of the MCSO records took place as did 71 percent of the RIT Campus Safety records. When combined: 63 percent of all of the recorded DVCs for the study area occurred during PM hours; 46 percent occurred during dusk hours alone; and, 63 percent of all of the DVCs occurred during low-light conditions.

A parallel assessment that could be assessed in the future using this data could also involve the typical commute times associated with the campus. Students typically don't arrive on campus until after the early morning movements of deer that are associated with sunrise. However, a much higher percentage of the campus population moves to leave the campus during the evening movements of deer that are associated with sunset. Also, there are significantly fewer people on campus during the summer months when most students and faculty are on break. These observations may create a bias in the data that is not normally present in areas that do not have a large academic population influencing traffic patterns.

One way to use this information to help reduce the occurrence of DVCs around campus would be to use a notification system to warn commuters to the RIT campus of the increased dangers at certain times of the year. According to Al-Ghamdi and Algadhi (2004) periodic reminders produce the best results with regard to motorist attention to hazards. The notification system could be as simple as a mass distributed email or as elaborate as a signage system.

Trail Analysis

Analysis of the trail system produced a map of trail locations and density pre-Park Point construction. There is a strong correlation between the occurrence of DVCs and the presence of deer trails at the corner of John Street and Jefferson Road in Figure 19. Figures 18 and 19 serve as the base analyses that created the comparison. An interesting observation in Figure 19 is the presence of trails with relation to the presence of undeveloped areas, which can be correlated with the areas where DVC incidents are present too.

The expansion of the understanding of the trail system in the now partially developed area north of Perkins and east of Lowenthal (Figure 18) to include the entirety of the Super Block would be a large step toward focusing a natural resource management plan to areas that need it most. This figure gives some insight to the travel areas preferred by the resident deer population and, if expanded, could be used to characterize the movements of deer and potentially other animals over the entire Super Block. This information could then be used to define focal points where animal vehicle collisions are most likely to occur.

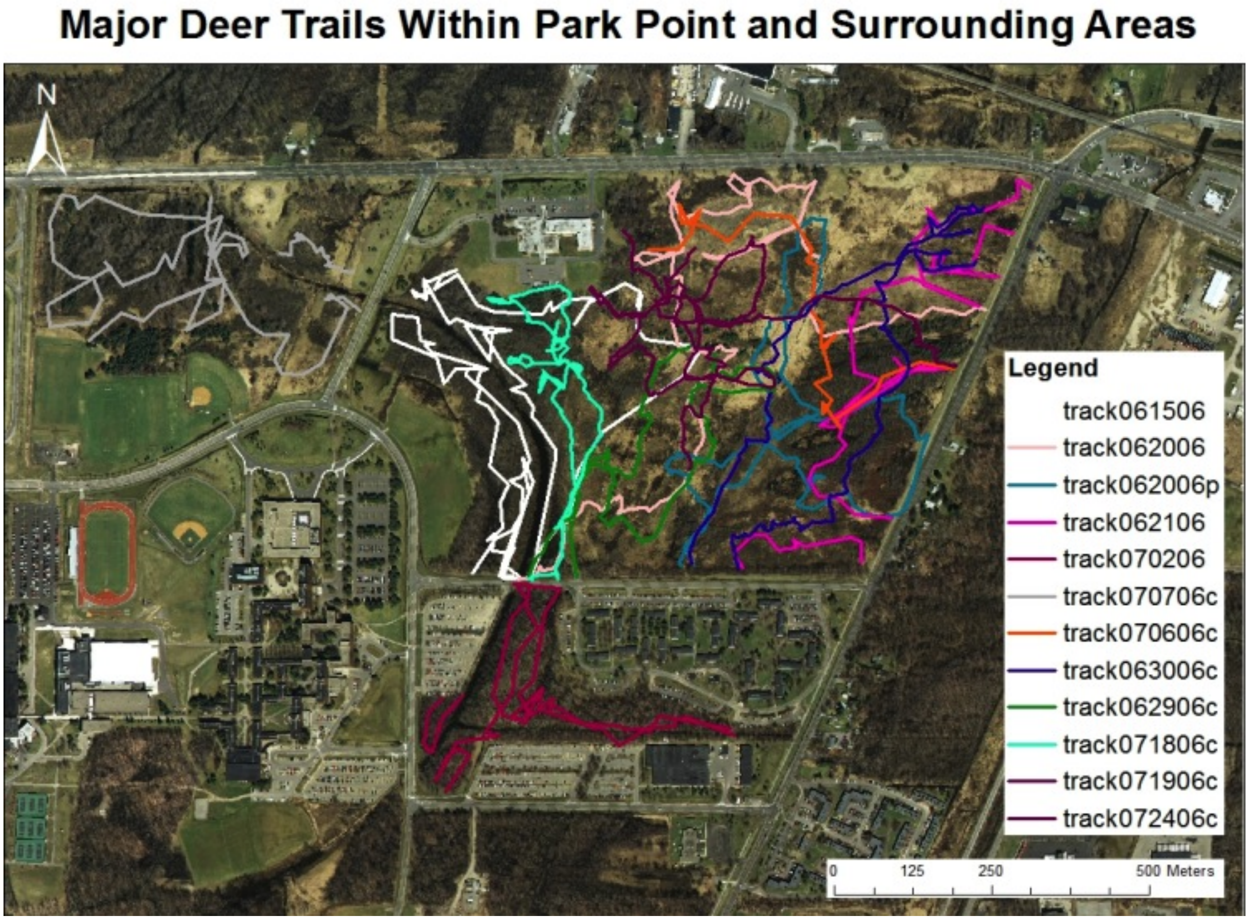


Figure 18.

An understanding of how factors influence the occurrence of DVCs at RIT and its surrounding roadways will increase the effectiveness of the plan put into place to combat this issue. Figures 18 and 19 can also be used to identify ideal locations for trail cameras and other forms of observation. Observation can help identify deer traffic volumes and population estimates.

Traffic volumes can further assist with targeting key areas for natural resource management and population estimates can be used for creating a herd health assessment.

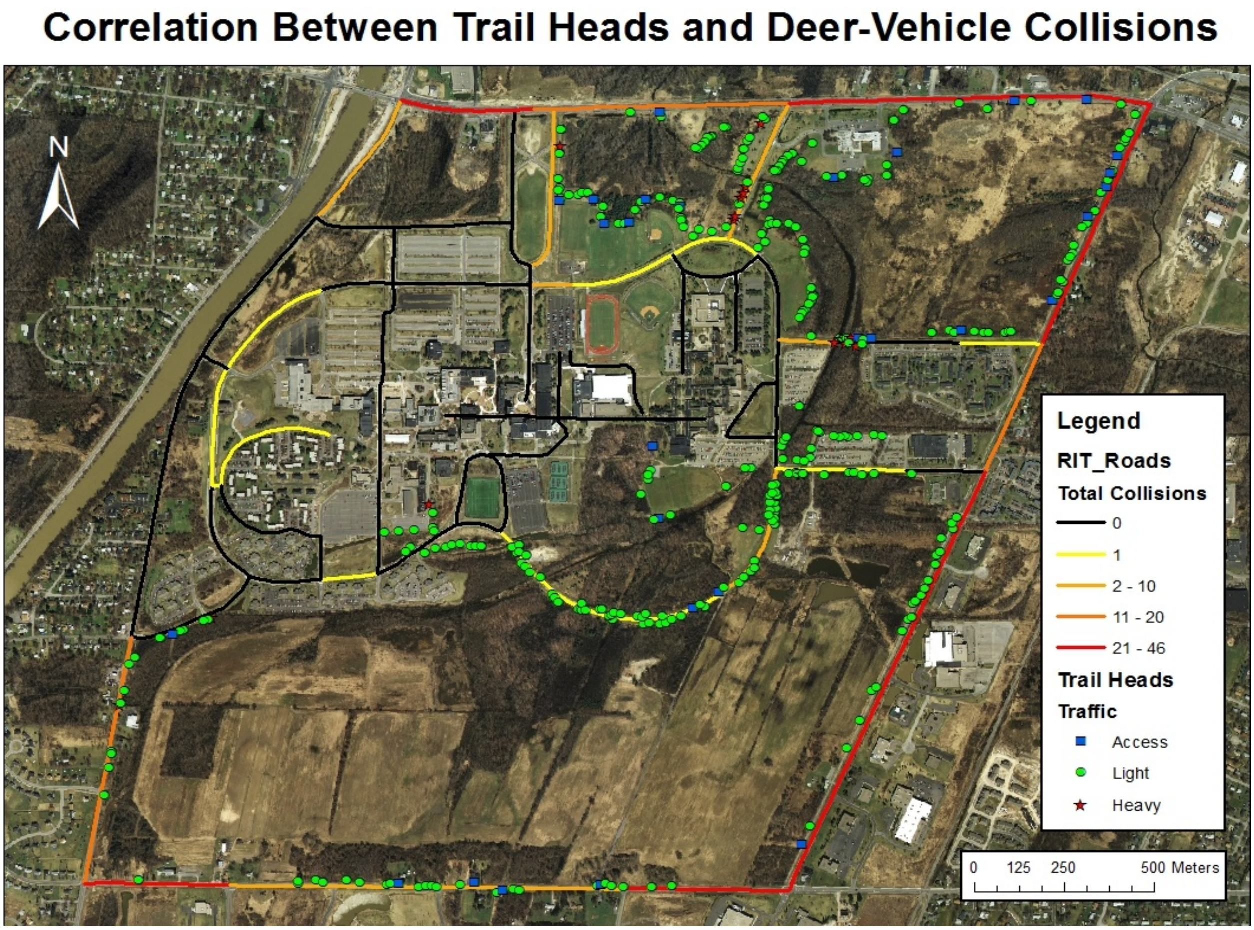


Figure 19.

Figure 19 gives powerful validation to the correlation between the presence of deer trail exit/entrance points and the occurrence of DVCs in some areas, such as the northern section of John Street. In other areas, like the eastern portion of Bailey Road, the correlation does not seem to make sense; however many factors can contribute to the presence of a DVC hotspot including, but not limited to: speed limit, distance between designated stops, traffic volume, visibility, land use classification, and deer activity levels.

Quantitative Analysis Results

- **Hyperspectral Analysis**

After conducting the spectral comparison between a winter time whitetail deer hair spectral signature and several potential confuser objects such as soil, pine cones, pine needles, grape vines, tree bark, and leaves it can be concluded that filters for the VNIR and SWIR wavelengths from 866-999nm, 1615-1679nm, and 1920-2033nm are most useful for detecting a whitetail deer in its natural habitat when using a ten percent difference in spectral signature from winter deer hair.

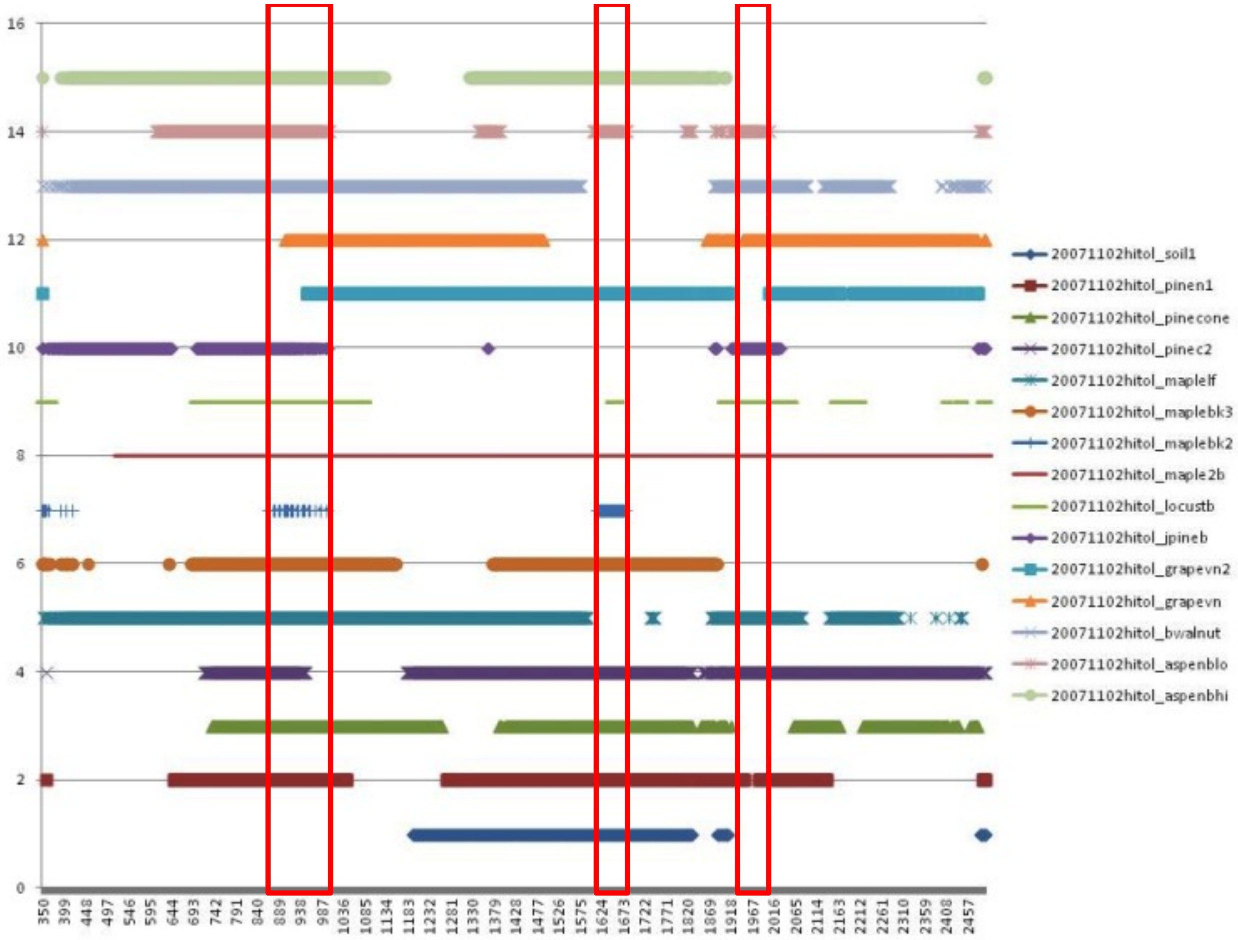


Figure 20.

The addition of MWIR imagery in scenarios where the average background temperature is significantly below 23 degrees Celsius (based upon the exterior temperature of a single hunter-harvested sample) can increase the success of this methodology (Martin, 2011; Kissel and Tappe, 2004). Thermal infrared imagery has been used for decades in wildlife population estimate methodologies (Kissel and Tappe, 2004). This method could be enhanced by adding small target radiometric restoration techniques to detect any deer that are mostly masked by habitat. The ideal timeframe to execute this approach to deer population estimation would be in the wintertime after snowfall and/or while snow is on the ground (Kissel and Tappe, 2004). This situation will cover most confuser objects with snow and the temperature difference between snow and a deer will make thermal imagery very effective (Israel, 2001).

The angle of incidence of sunlight with respect to the sensor's imaging angle in a snow-covered scene situation also needs attention. The possibility of reflection upon the snow is a real factor here that could mask the presence of deer by saturating the sensor with reflected sunlight. As indicated by Israel (2011), detection capabilities for infrared sensors are best in the absence of sunlight. In the absence of snow an alternative situation for optimal imaging conditions would be in the winter after several days of sub-freezing temperatures (zero degrees Celsius or 32 degrees Fahrenheit). This scenario would ensure a background temperature low enough for the MWIR imagery to enhance the spectral analysis results.

- **Longwave Infrared Analysis**

The pixels formed by the Wildfire Airborne Sensor Program (WASP) longwave infrared (LWIR) sensor have a ground sample distance (GSD) of approximately 3 feet. When attempting to locate a whitetail deer using this sensor it is important to remember that the average deer is about 6 feet long and roughly 12-14 inches wide. A portion of the length of a deer is its head, neck and tail, which are even narrower than the body, so the actual detectable length of a deer is really only 3-4 feet. This means that the average deer is a sub-pixel target for this sensor. Thus some form of small target restoration (SMTR) must be performed to determine the actual temperature of the target (deer).

Another consideration when attempting to resolve a deer from the background using LWIR imaging techniques is that the outer layer of a deer's hair suppresses the actual body temperature. The approximate outer temperature of a deer is 70 degrees Fahrenheit (based on a single hunter harvested sample). This means that during the warmer seasons such as late spring, summer and early fall there will be little difference between the background materials of a natural scene and the outer temperature of a deer. During the colder seasons including late fall, winter, and early spring there may be a large enough difference between the exterior temperature of a whitetail deer and its background to resolve it from a scene. Another advantage of the cold weather seasons is a lack of foliage on trees and low shrubs. This means a greater ability to see past the canopy and down to ground level using an overhead imaging system.

The optimal time of day to image for deer using infrared techniques is nighttime, preferably between the hours of 2000 and 0500. This time frame creates the largest delta between target and background temperatures while also including time frames of high deer activity.

All of these factors combined together increase the likelihood of capturing a snapshot of the RIT campus deer population using the infrared sensor suite onboard WASP during a single collection. The downside to nighttime collections of sub-pixel size targets is that it would be very difficult to verify which suspicious pixel clusters were target and which were simply variations in the background using visible bandwidths. The positive impact of daytime collections in winter-time is that there will still be enough contrast between background and target for analysis and there is a potential for co-collection of VNIR and HSI data for confirmation of the presence of deer.

- **Personal Observation Analysis**

The personal observation results are highly dependent upon commute direction, origin, and destination. Most deer observations occurred in areas that were near the Red Creek riparian buffer. Most of the observations recorded involved between 1 and 3 deer or no deer (Figure 22).

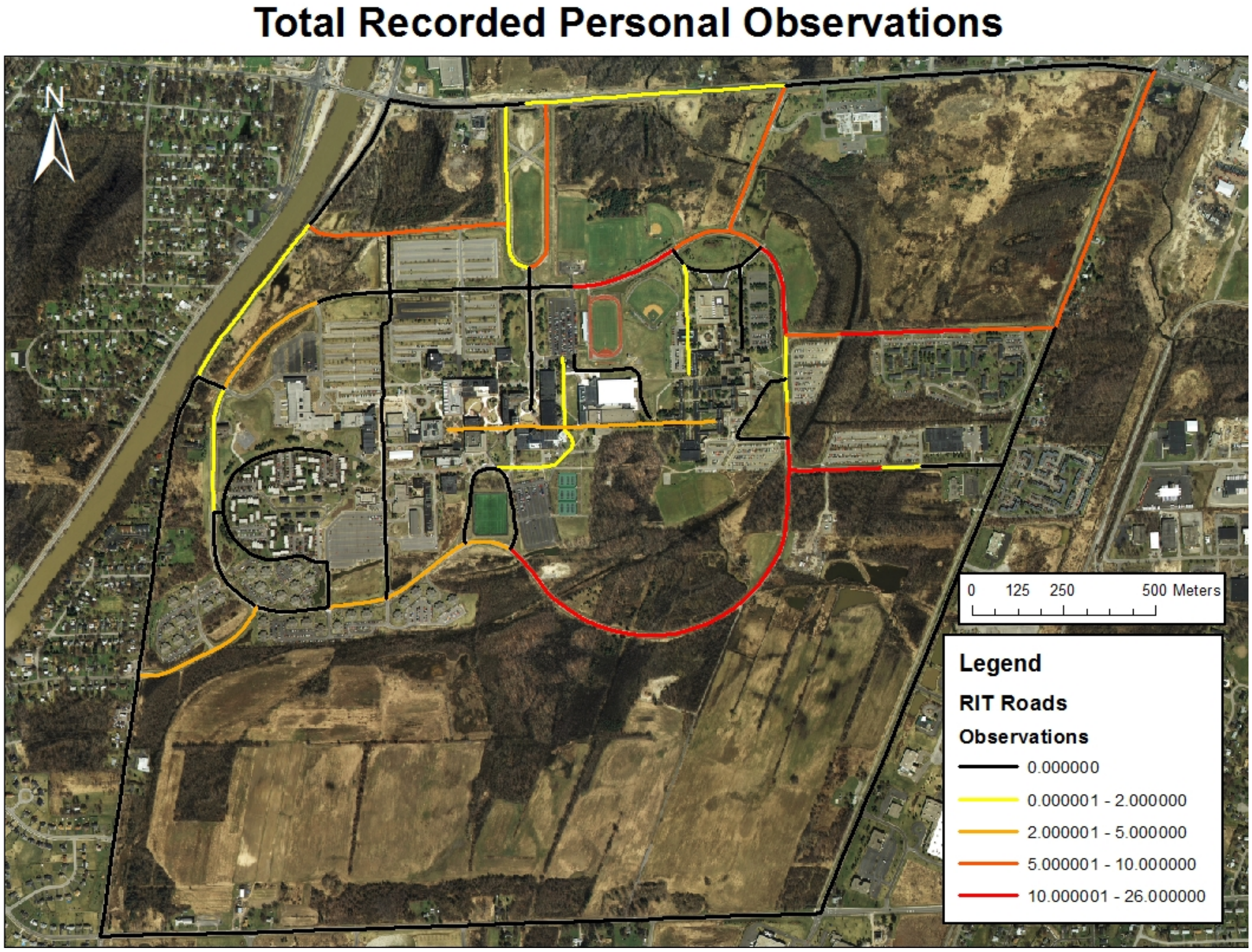


Figure 21.

The Perkins Road segment along the western-most apartments recorded the most deer sightings on surveys at 26, shown in Figure 21, while the section of Andrews Memorial Drive that runs between U-lot and the access road recorded 20 sightings. The section of Andrews Memorial Drive that runs between Wiltsie Drive and the access road recorded the third most survey sightings with 17.

Figure 21 can help determine where deer are most likely to be seen, while Figures 22 and 23 give a sense for where deer typically travel in groups and may assist with determining areas to focus a management plan.

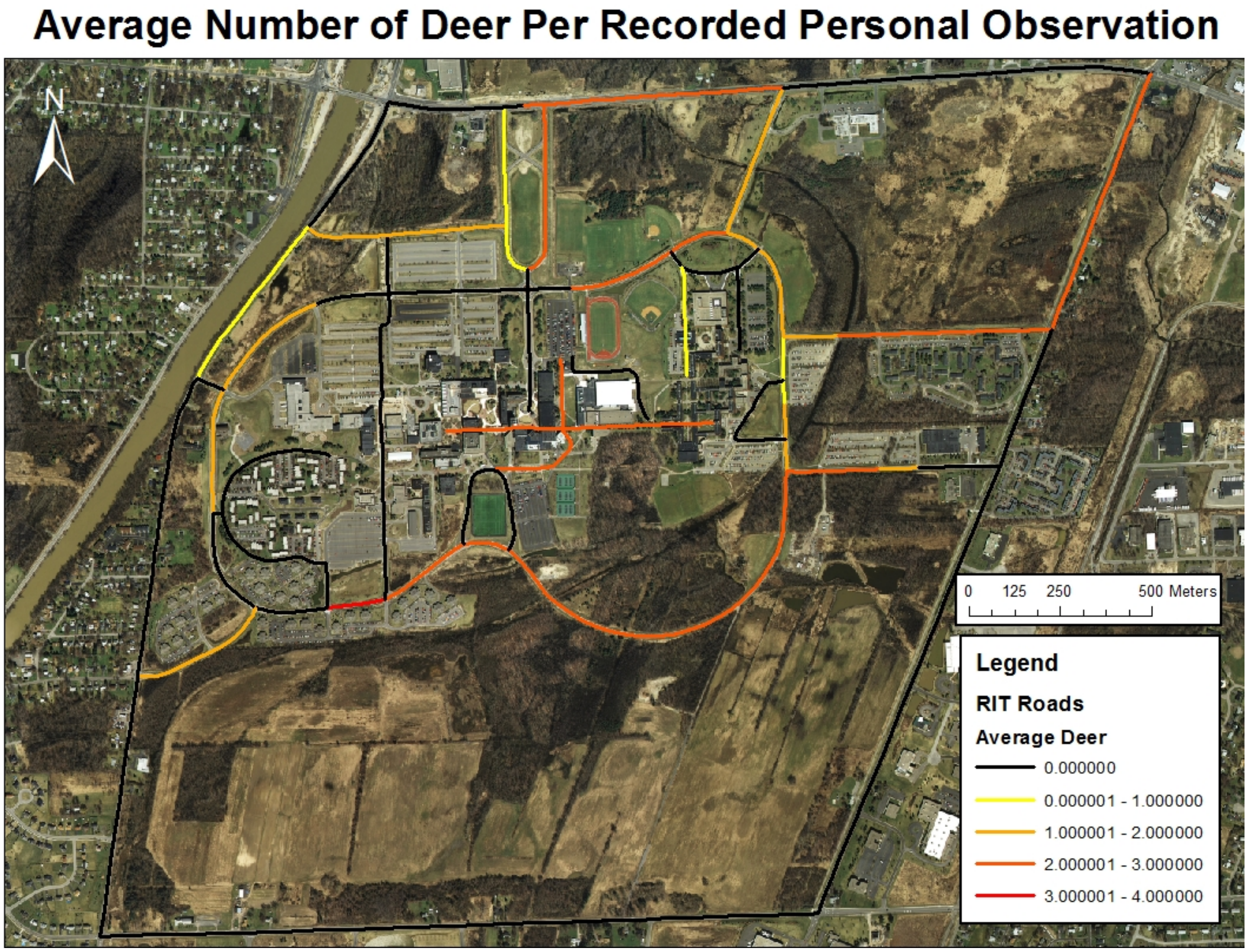


Figure 22.

This information is consistent with areas responsible for a significant number of the DVCs recorded along the interior roadways of the RIT Super Block. Figure 23 specifically shows where a management plan should focus first with regard to the interior roads of the Super Block; specifically along Andrews Memorial Drive between Wiltsie Drive and U-lot and along Perkins Road near the western Perkins Apartments.

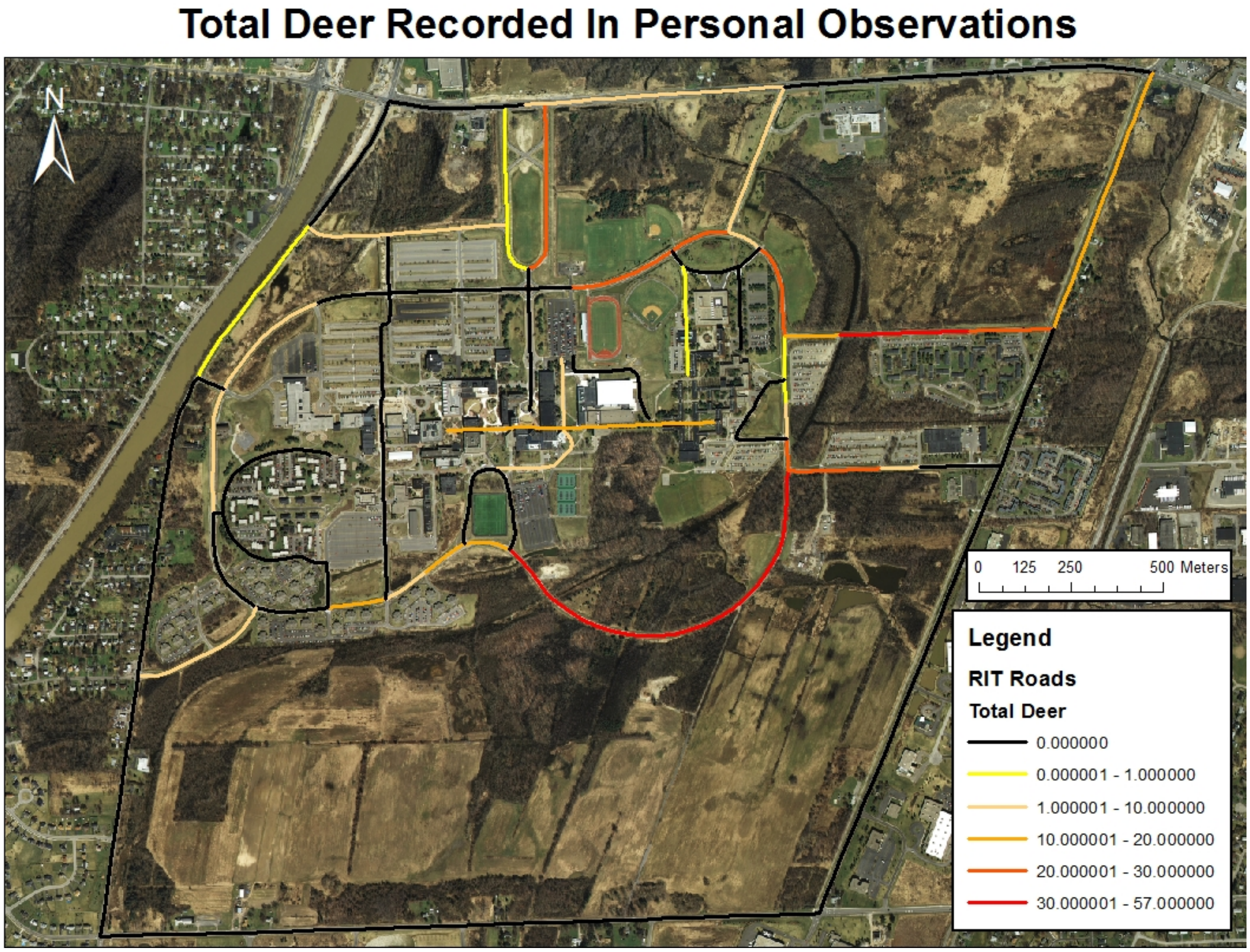


Figure 23.

- **Survey Response Analysis**

Out of 603 total survey observations in response to 1,089 recorded deer; female deer accounted for 53 percent of the total survey responses alone and fawns accounted for 28 percent. Table 1 also indicates the average number of each classification of deer seen per sighting.

Most of the survey related deer observations involved young (fawn) and female deer. The comparatively low number of male and unidentified deer is probably due to a lack of knowledge of the key features associated with each option for this field. In the future, pictures should be provided to assist participants with accurate visual depictions of male, female, and fawn.

Survey Statistics

	Female	Male	Fawn	Undefined Deer
Total Responses	321	18	170	94
Total Deer	589	20	306	174
Average Per Sighting	1.83	1.11	1.8	1.85

Table 1

Table 1. .

As with the personal observations, commute direction, origin, and destination are very influential factors with regard to volume of sightings along any given road section. The survey was mass distributed to try to avoid this influence, but the impact can still be seen on the interior roads of the Super Block and along Bailey Road. Most of the sightings occurred along the roadways bounding the Park Point area and areas near the Red Creek riparian buffer. Of note: these areas are mostly associated with deciduous and mixed forests as well as shrub/scrub land uses.

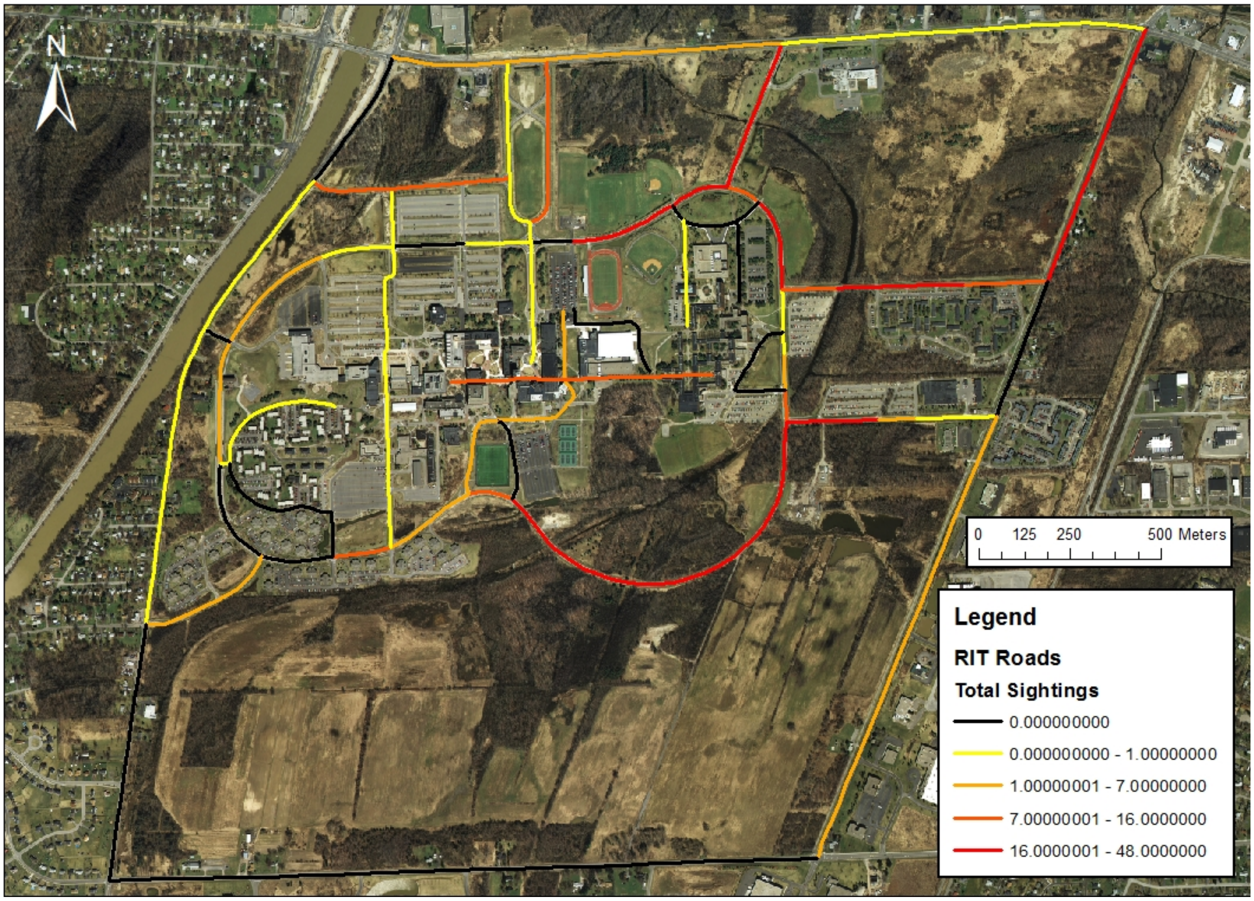

Total Recorded Survey Observations

Figure 24.

Like the results for the personal observations, the Perkins Road segment along the western-most apartments recorded the most deer sightings on surveys with 48; while the section of Andrews Memorial Drive that runs between U-lot and the access road recorded 47 sightings. The section of Andrews Memorial Drive that runs between Wiltsie Drive and the access road recorded the third most survey sightings with 27. Figures 21 and 24, can help determine where deer are most likely to be seen, but may be misleading with regard to the fact that most sightings are probably very dependent on the daily commute to and from campus for the observer.

Contrary to the personal observations, the survey results indicate that deer on the RIT campus tend to travel in groups of 2-4 individuals rather than alone.

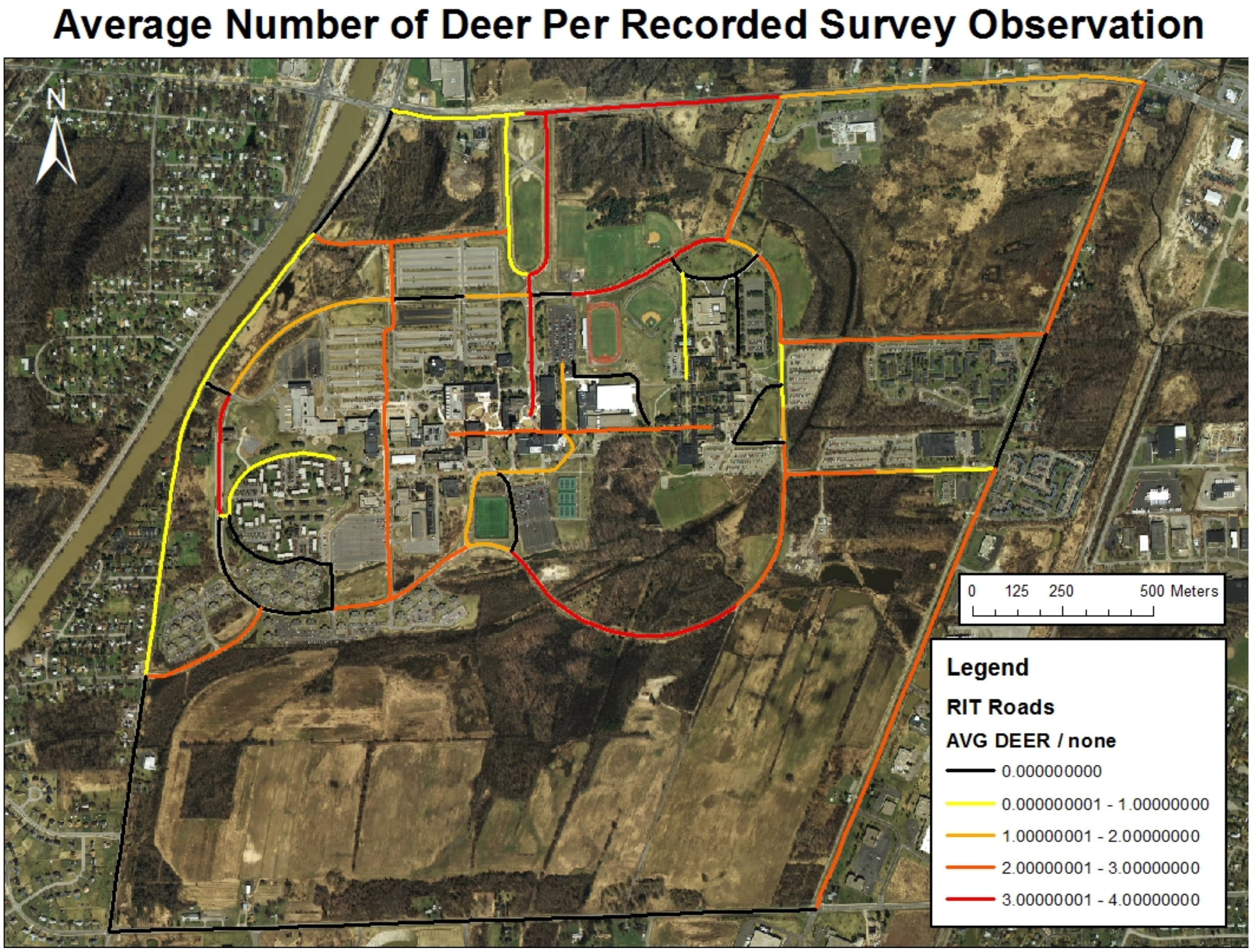


Figure 25.

However, the most deer were also seen along Andrews Memorial between U lot and Wiltsie and along Perkins road between K lot and the western Perkins apartments. The major difference between personal observations and survey observations is the large number of deer observed along the Andrews Memorial Edmund West section of roadway. This could reflect commuting habits as vehicles turn toward the academic side of campus from Lowenthal Drive.

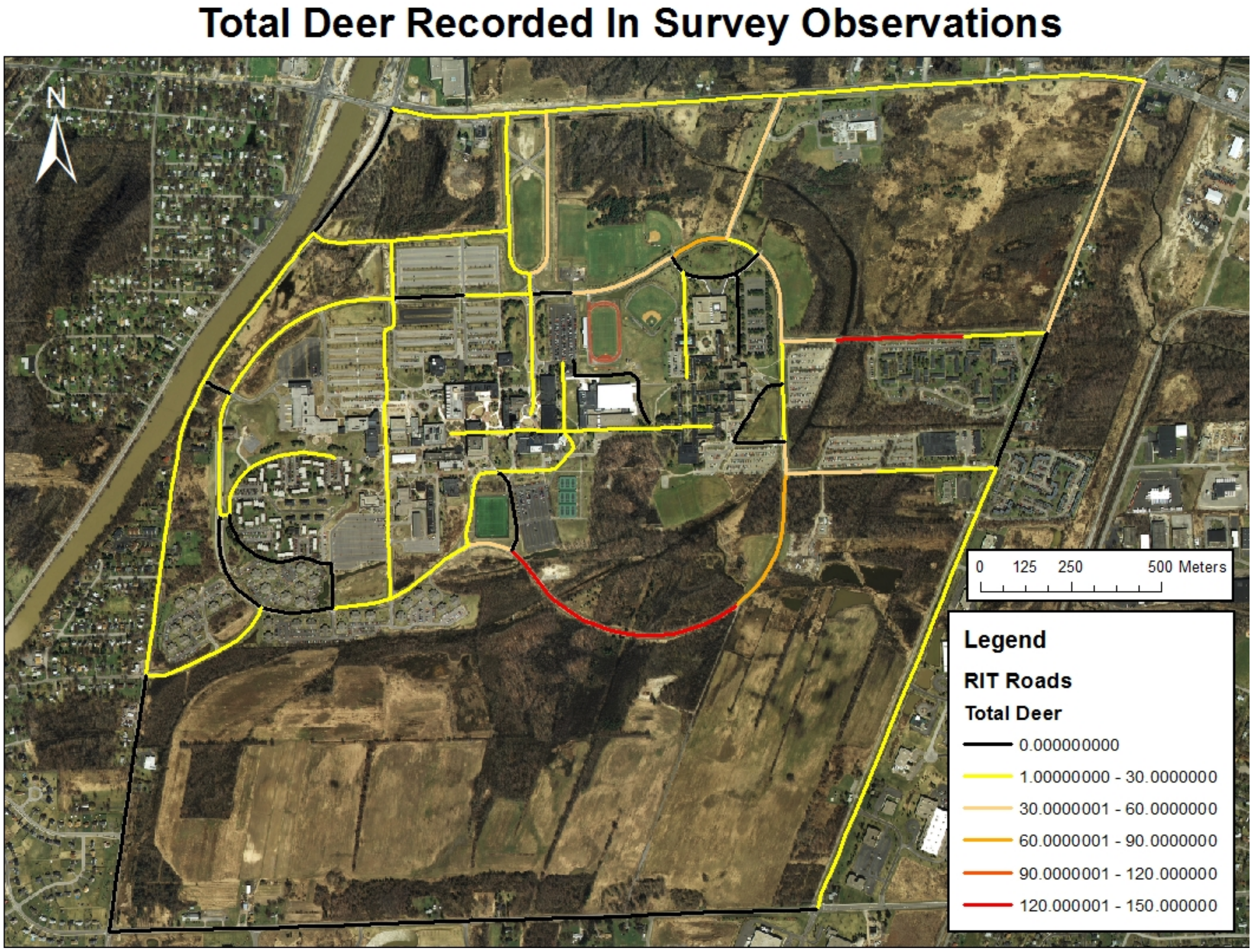

Total Deer Recorded In Survey Observations

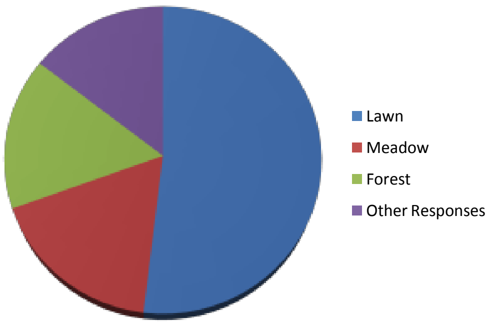
Figure 26.

Based on general comments of past and present deer sightings, Figure 26 illustrates the expected presence of the deer population on campus from the perspective of the faculty, staff and students. This, along with Figure 23, shows where a management plan should focus first; also in addition to the areas with high DVC occurrence rates.

Other quantitative responses that could not be displayed in map format included surrounding habitat and current weather at the time of the observation. These responses were analyzed statistically to determine if sightings occurred more often in weather or habitat specific situations.

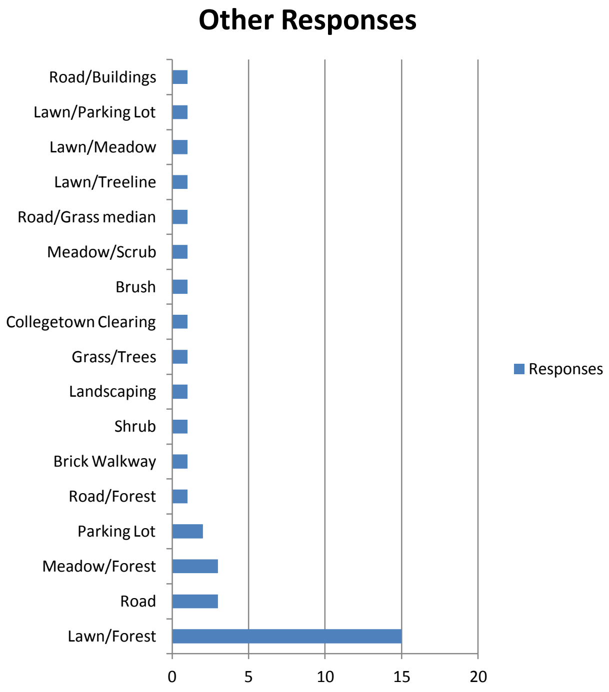
Sightings in areas identified as ‘Lawn’ accounted for 52 percent of all survey responses, while responses ‘Meadow,’ ‘Forest,’ and ‘Other’ accounted for 17.5, 16, and 14.5 percent of the total respectively.

Survey Habitat Responses



Total Responses: 262

Graph 9

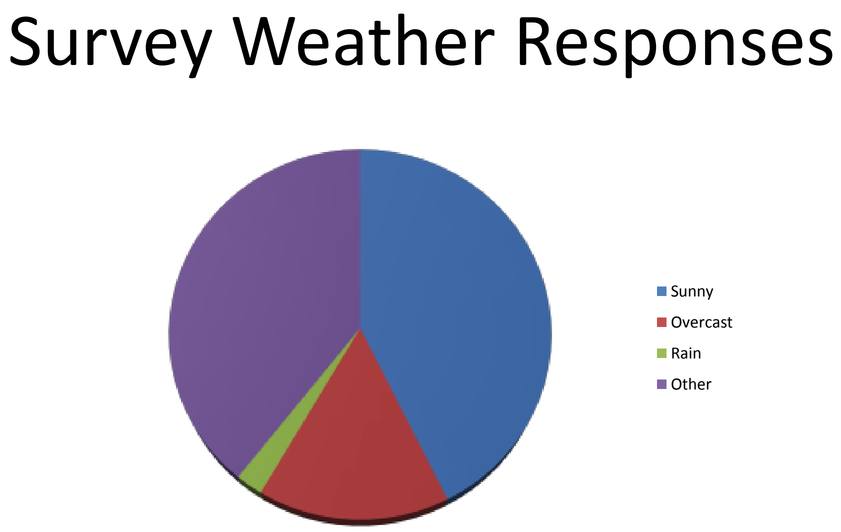


Graph 10

Graphs 9 and 10.

Most of the ‘Other’ responses account for transitional areas and man-made structures. Future surveys could include these two additional options in order to reduce the number of ‘Other’ responses.

‘Sunny’ accounted for 43 percent of the total weather related responses; ‘Overcast’ responses accounted for 16 percent; ‘Rain’ accounted for 2 percent; and ‘Other’ accounted for 39 percent of the responses.

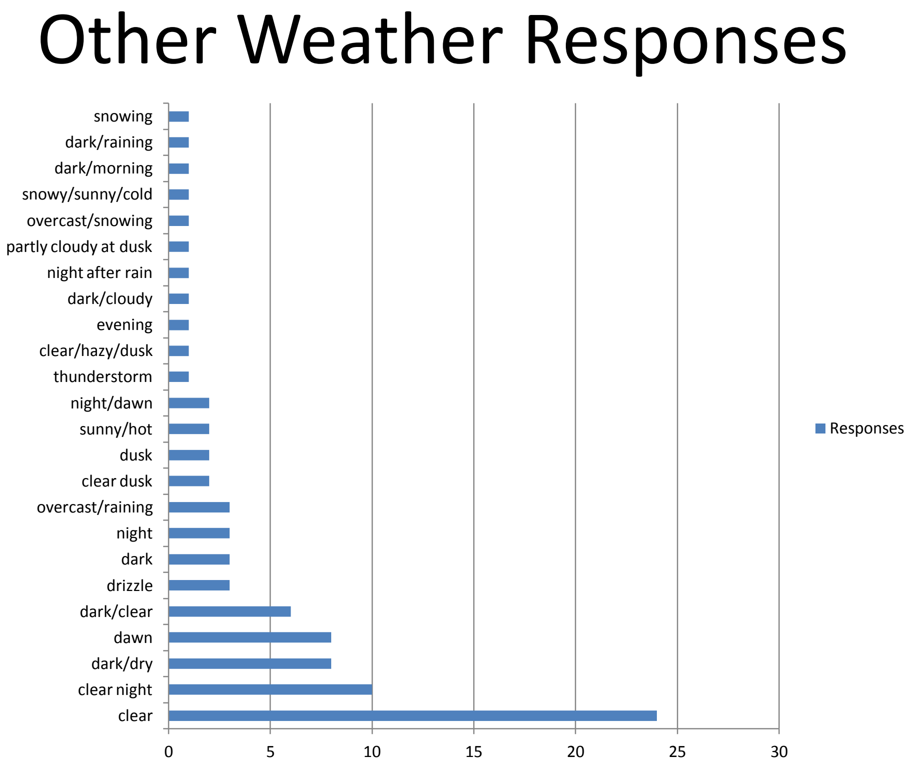


Total Responses: 267

Graph 11

Graph 11.

Responses that include the word “clear” account for 41 percent of the ‘Other’ responses, so this should either be included as its own option or it should replace ‘Sunny’. Other forms of precipitation account for 10 percent of these responses, so the word “precipitation event” should replace ‘Rain’. A depiction of the time of day accounts for 20 percent of the responses, which means that further guidance may need to be provided for follow-up surveys to ensure proper use of the form.



Graph 12

Graph 12.

The majority of deer sightings occurred during sunny or clear weather. This possibly indicates that deer prefer to move during these weather situations. A follow-up study could try to assess whether deer move more before or after a significant weather event to try to further narrow down patterns of movement for a more specific DVC avoidance strategy.

Qualitative Analysis Results

As is the case with most surveys, the responses recorded for both the paper copy and web-based surveys were very consistent and even voluminous at times when the survey was first distributed. However, after a few weeks went by (or even a of couple days in some instances) the number of surveys that were submitted decreased exponentially until only a couple per week were recorded.

In total there were 116 responses to the last distribution of deer sighting surveys (to the faculty of RIT), in which the respondents took advantage of the "Additional Comments" text box. Of these respondents, 31% noted the location of the deer in relation to the area in which they saw it; 28% noted the activity in which the deer was partaking, whether that be crossing the road, browsing, etc.; 16% gave a response unrelated to the study; 5 % gave a description of the area in which they saw the deer, and; 20% gave additional details that may not have been particularly about the sighting but helped to give further context overall.

Those respondents that gave a more detailed location of the deer that was/were involved in a sighting often used vegetation parameters or landmarks to further explain where the deer was observed. In a few instances the use of a pair of the road segments was implemented because the separation was not definitive. One respondent gave a very descriptive explanation of the locations of the deer which they had observed: "various spots around campus-south loop east of U-lot-athletic field north of K-lot-grassy area north of bldg.60 and athletic fields across Andrews from bldg.60-north of Andrews and west of Lomb---deer are out nightly and vary on weather conditions and time of year---they vary from a few to as many as 50 or 60 some nights--the busiest time is between 1:00am and about 5:30am- after that they start fading back into the woods towards sunrise---some of them browse fairly close to the bldgs (sic) on the academic side". Other examples are more succinct, such as one observer's quick explanation of where a deer was located within a particular road segment: "Actually 4 at the edge of the woods on the Rugby Field 8 or so behind the baseball diamond opposite GFH and 8 or so more in the lacrosse area next to that diamond. "

Observers that gave a feeling for the activities of the deer had the variation in their responses that can be expected from observing any living creature as it interacts with its surroundings. Some observations were interesting because they indicated where a deer had actually crossed the roadway. Others indicated activities such as if a deer was lying down, browsing, walking (and in which direction), standing, etc. An example of one such observation is "1 deer started running quickly and stopped at the fence near the baseball field across from the field house." While this is a very informative observation, there are still others that are much more descriptive and detail oriented than others in a sense: "The deer ignored a man running past it;" "The deer was scratching itself with its hind foot;" "I was in a car;" "I now know how to tell the sex of deer: the females have a rounded top of their head; the males have a flatter top of their head, and maybe have small bumps where their horns are growing. You may want to include photos of each sex." This last response indicates that the study sparked a genuine interest to learn about deer in at least one participant.

A number of the persons that took part in the survey simply commented on things that had nothing to do with the actual sighting. They used the open comment box as a platform from which to project an environmental point of view or to give appreciation for the fact that a study with relevance to the local population of wildlife was being undertaken. These responses are important to gain the viewpoints of the persons participating in the survey and determining how that viewpoint may affect a response. A perfect example of this occurrence can be seen in the comment: "My comment is that I am appalled at the development on Jefferson that destroyed the forest there. It just emphasizes the arrogance of man. Everything belong (sic) to him, doesn't it." An example of a person that wanted to show their appreciation for the wildlife in general on the

RIT campus wrote “Deer was lying in the grass. just a side note, for three years now i have been observing the same female fox birth a den of pups in the spring. just past the red barn up on one of the banks which run along river road. The pups bathe in the sun in the morning with mom right by, about four pups. there is a FMS stake right near the den so i hope they are not going to disturb the new family. i haven't seen them come out yet. Just an FYI. also saw a mink run across the road the other day next to lot u. You probably think I'm nuts, but i love the wildlife on campus. Good luck with your studies. :) (sic)” In addition to those comments that had to do with the environment there were some that were simply appreciative for the attention given to RIT’s wildlife through research: “Thanks for doing this study - I hope it helps the deer thrive on campus. They are so awesome to watch!” The list of extraneous comments is exhaustive; however these few examples give a good illustration of what some observers wished to share.

Several survey participants took the time to further describe the surroundings that the deer was in. These descriptions vary with complete dependence upon the area on campus that the deer was seen, as well as the season during which the sighting occurred. One respondent took the prerogative to include that about “about 5 inches of snow” were present for that particular sighting. These details add context to the seasonality of some observations as well as, in some cases, the surroundings that the deer may prefer. An example of a comment that helped to further define the time of a deer sighting was the comment that said simply “at Dusk“.

The last category of responses did not necessarily pertain to any direct observation in particular, but held some significance in terms of a suggestion to improve the survey, an observation that occurred at another time that was not specified, etc. These comments may not have directly contributed to the study, but they helped with ways to improve the survey itself for future use or gave indications to other observations of deer at undetermined times or in places adjacent to the RIT Super Block. One such comment was "I used to see deer all of the time on campus. The locations were often in the College Town area and the fields between NTID and the Radisson Hotel/Clarion? I have not seen a deer in these areas or any other areas of campus in a long time. I do live near campus, in back of the red barn Legno gas station area. I have seen large herds of deer roaming in these areas. More move through my back yard on a regular basis than ever before. I believe the deer have had to move because campus no longer accommodates them. I worry about their safety and well-being. Having enough space and enough food is a real issue." Some even involve suggestions such as "After work (4:40pm), I usually observe a number of deer at the soccer field across from D Lot near the fence. Years past the deer would mainly be near Lowenthal towards the Radison. Be sure to ask Dr. Simone, now commuting from Keuka Lake, he and wife Carolie have had a few auto encounters with deer!"

It was very difficult to categorize most of the answers because they cover several of the codes at once. Most of the responses that were collected from the comment text area overlapped several of the categories at once as the respondent tried to include as much information as possible within the space provided. This can be seen in many of the examples included above, however there are still some that can further illustrate the point such as "I ride the bus to work in the early morning hours. The rugby field, the U-lot access road-south side by woods and the U-lot access road on the back bend toward Wiltsie Road are usually populated with deer in the morning. Also the back north east corner of the Ball diamonds on the front of the campus near LBJ. Also on John Street in the old corn fields toward Bailey Road. I observe them almost every morning.

Always Does, rarely a Buck. Right now, the Does are hanging around the campus, birthing will begin soon and the campus is a safe area, not many predators to deal with as they give birth." Yet another example can be found in "I've seen deer near the main entrance, coming from the right (if I am leaving RIT) for a long time. The say in question I saw 3, but I've seen many more than that before. Also, they do sprint across the road as well, and people have had to stop. I've seen 4+ at times in that area."

This qualitative study was largely designed to add context to the survey that was already being distributed. It was meant to give context to the quantitative responses collected by the initial survey.

According to the data, the observations were fairly evenly distributed across the classes chosen to represent the data. The only class that was really under-represented was that of the site descriptions; and that can be accounted for by the fact that the survey already asks for the surrounding vegetation present along with the option to fill in a text box for 'other'. The next lowest classification was of responses that had no real relevance to the study. This was largely made up of respondents that either had a more global view related to environmental science or those that wished to appreciate other areas of nature as well.

CONCLUSIONS AND FUTURE ANALYSIS

The main purpose behind conducting this study was to stimulate an interest in the subject matter and to create the potential for follow-up studies, while exploring documented DVC mitigation plans to assess what may help reduce negative human-deer interactions at RIT.

Deer-Vehicle Collisions

The next DVC study conducted for the RIT Super Block should concentrate on determining whether the trends seen in this study continue or diverge. Of particular interest will be the impact that the construction of Park Point has had upon the local deer herd and its historical movements. These movements should be reflected in the location of DVC hotspots and areas that display an increase in the occurrence of DVCs.

Trail Analysis

Updating the trail analysis conducted between 2007 and 2008 will accomplish two main objectives: it will determine if deer herd movement patterns have changed; and it will provide updated locations for heavy use trails and high deer traffic areas that require attention from a natural resource management plan. Another benefit to this type of analysis is creating a deep understanding of the habits of the local deer herd at RIT and how to enhance the habitat for its benefit while also creating the necessary knowledge to prevent negative human-deer interactions.

Remote Sensing Analysis

A follow-up study regarding the remote sensing techniques proposed should include an assessment of the detection rate of the methodology described using hyperspectral or multispectral imagery with a concentration on the previously defined bandwidths. Detection rates are necessary for determining the success of population estimate methodologies (Kissel and Tappe, 2004).

Quantitative Observation Analysis

- **Personal Observations**

In the future, personal observations should be replaced by the use of trail cameras (Kissel and Tappe, 2004). The cameras should be placed along heavy use trails and in areas where there are an elevated number of sightings. In an effort to expand upon the current results, it would be useful to place cameras in areas with very few or no observations to note if there is a deer population presence. Cameras will give insight to the deer traffic volume along certain trails and in areas of high DVC occurrence. If placed along the bounding roadways, cameras may capture the number of deer that cross into the RIT Super Block too.

Another suggestion for future studies would be to involve more than one person in the regular recording of personal observations in an effort to reduce the amount of time that lapses between observations of significantly separated segments of roadway.

- **Survey Observations**

The majority of survey observations that included surrounding vegetation information involved 'Lawn' associated areas. The 'Other' responses were mostly interpretations of transitional areas and manmade infrastructure so future surveys should try to include those as additional options.

'Sunny' and 'Other' accounted for the majority of recorded weather scenarios in survey responses. In the future, 'Clear' should replace 'Sunny' and 'Precipitation' should replace 'Rain'. Further guidance needs to be given regarding depiction of the time of day as 20 percent of the responses for weather involved words that are best associated with a time of day.

Qualitative Observation Analysis

Some improvements that can be made on this survey for future use were hinted at by some of the respondents and others became apparent as observations were submitted. The first improvement is that the observer's name is not necessary for our purposes and thus can be dropped as one of the fields that are included. There is the option to not include one's name and still submit the survey, but it would be even more impersonal to simply take away the option to identify oneself. One large drawback to this would be the inability to help mold a dedicated participant's answers to better serve the study.

Another improvement would be to adjust the input of time to a 24-hour format or include a radio button AM/PM input that needs to be selected for submission. This will simplify the process of figuring out what an observer means when they put down a particular time stamp and then omit the AM or PM suffix. Mostly this can be rectified by simply looking at the timestamp on the email that is received, but sometimes even that is slightly confusing. To have the time entered in only a 24-hour format or restrict submission until the appropriate time is entered would ensure that the correct time is recorded every time and eliminate any discrepancies in the data.

One comment that kept surfacing was how to tell the difference between deer genders and ages. The survey is flawed in that it assumes that the observer has a previously acquired knowledge on how to differentiate adult deer from juveniles and male deer from females. One way to solve this may be to adjust the survey so that it is more descriptive in the definitions of male vs. female deer and fawn vs. adult. This may involve asking the observer what number of deer had either antlers or spots for the spring/summer season (differentiating between the two of course so that an accurate number for each category can be obtained). Yet another method may be to provide a visual aid for reference. This would involve acquiring images that show a stereotypical fawn, doe, and buck. Meaning that the fawn will have spots on its coat, the doe will look like a plain deer and a buck will have antlers on its head. This will help to solve problems that certain observers had with identification. It can be noted though that during a certain portion of the year the bucks will be misclassified as does because they have dropped their antlers and alternate means of identification must be used to determine a definitive sex type.

Yet another comment that several observers brought up was the fact that the map may have been too small and/or confusing to read accurately. This can be remedied by first, enlarging the image in which the map is displayed. This will assist with the determination of the extents of specific road segments as well as improve the visibility of the numbers and colors associated with them for easy identification. The enlargement of the image will also help to assist with definition of which segment is represented with which number, since some of the road segments are closely spaced in a back-to-back or parallel fashion. There is the option to click on the map for an enlarged image, but someone with poor eyesight may still have some difficulty in seeing a separation of segments, or may miss the prompt to click on the image all together. Also, the colors associated with some of the road segments are fairly similar in hue. The only setback in fixing this problem is that there are only so many colors that can assist in differentiating between 60 individual road segments, and the human eye can only effectively tell the difference between 5 different hues for each separate color.

The text area that is provided for comments can be altered to hint to a certain direction to be followed when including ones additional comments. This may be possible to accomplish by changing the title associated with the comment box, which is currently “Comments:”. In order to convey slightly more directionality to the request for additional comments a more appropriate title may read “Additional comments associated with your observation:”. This would help to lead the observer to believe that their comment must pertain to the observation as opposed to the current connotation that any and all additional comments are welcome.

Finally, the distribution system for this survey may be altered to ensure that a more varied population is reached and that they may actually take part in the survey. One difficulty that has been continually encountered is the observer that willingly participates once, and only once – largely due to a misperception as to the purpose of the survey. A possible solution to this problem may simply be to include in the preemptory statement that this survey is meant to be filled out and submitted for each individual deer sighting that one encounters. However, even then some can misinterpret the meaning and submit a separate observation for each individual deer that they see. This portion of the distribution is one of delicate wording and finesse. Further research needs to be conducted in the search for a statement that encourages the potential observer to fill out a survey for each sighting of deer that may be associated with an individual road segment at a single point in time.

The idea of the survey distribution was to reach as many individuals as possible so that for a given time on a given day there is the potential for multiple observations at multiple road segments. A population of several thousand was contacted via email each time that the survey was distributed (for the last two distributions). However, out of those that the email reached, most simply deleted the email as spam from RIT and were not able to participate in the study. This may potentially be cured by associating the email with a more eye-catching title such as a title that includes the key words 'deer population' and omits the relation to a survey until the body of the email has been reached, where it will be established that this survey will benefit a research project. Part of the problem with respondents is that as soon as the word 'survey' is encountered the email is deleted without a second thought. This is a dilemma that will continually plague those that choose to pursue the route of the online survey. If the survey is a continued effort, then it may be worthwhile to create an app that also allows the user to ask for explanations to any questions and link submissions to an email address.

If possible, the ideal situation would be to create a large email account and send the survey to the entire RIT community. This would mean that the survey reaches over 15,000 people which would hopefully result in an increased response, which may in turn provide a more comprehensive "snap-shot" of the deer population on a given day, at a given time, in multiple locations. Most of the population would still fail to respond, but ideally enough to accomplish the survey goal would reply, and this would ensure a very comprehensive database of observations (including additional comments to provide further context to submissions).

Deer Management Plan

Accoring to a Xie et al. literature compilation too many deer cause unacceptable crop damage (Allen and McCullough, 1976; Conover and Decker, 1991), deer-vehicle accidents (Conover et al., 1995), transmit disease (Wilson and Childs, 1997), and adversely impact forest regeneration (Alverson et al., 1988). RIT is specifically concerned with reducing the occurrence of deer-vehicle collisions. This study attempted to define factors that influenced the occurrence of DVCs and pinpoint the locations that record the most incidents before proposing a natural resource management plan that focuses on reducing the overall number of DVCs on and immediately surrounding the campus.

The most effective deer management plan would be to fence the perimeter of all roadways with fencing higher than 9 feet and connect the fencing to a series of underpasses and overpasses that allow for the easy, yet controlled passage of wildlife. RIT would then hire a contracted biologist to administer an immunocontraceptive to passively, yet intrusively control the deer population.

Al-Ghamdi and Algadhi suggest that use of reflectors and/or mirrors along roadways as deer deterrents may not have a significant impact upon DVCs; however, the targeted placement of these tools may provide opportunity for a new study upon their effectiveness. Targeted placement can be accomplished by using the trail head information and angling the incident surface of the mirror/reflector so that the beam of light from headlights is redirected into the eyes of deer that use these trails.

According to Xie et al. stakeholder sentiment must be taken into account when dealing with natural resource management, specifically white-tailed deer, in addition to population assessment and habitat carrying capacity. Stakeholders in this situation include, but may not be limited to: RIT faculty, staff, and students; RIT Facilities Management; RIT Public Safety; Monroe County Sheriff's Office; Monroe County; Department of Environmental Conservation; and the Town of Henrietta. In the Comments section of the surveys an initial assessment of the RIT community's sentiment toward the resident deer population was that the deer are a positive influence. This survey should be expanded upon to more adequately assess a campus-wide sentiment toward the population and RIT will need to decide if the community will have a voice in the natural resource management plan for the campus as that could also be a part of the survey. The sentiment of the other stakeholders has not been adequately assessed.

The use of fences and over/underpasses is not practical for RIT and would adversely affect the ambiance of the campus. The use of controlled access bow-hunting as a revenue building option of population control would need to be decided between the RIT stakeholders including, but not limited to: the student body, Campus Safety, Financial Services, Public Relations, faculty and staff, and the president of the school. The effectiveness of immunocontraceptives would depend mostly on the movements of the local deer population with regard to how many deer “commute” to the Super Block nightly for food.

The best options at this time for RIT with regard to reducing the occurrence of deer-vehicle collisions include the targeting placement of the unproven reflectors and mirrors along areas that have heavy use deer trails and/or a heightened rate of DVCs. This would provide the opportunity to revisit a study of effectiveness for this system. Also, a sign system that involves motion detectors and flashing warning lights, similar to those seen along large animal migration routes in western states, may remind drivers to be cautious when an animal enters the right-of-way near a road. Again, any system that is employed here can be the subject for a study of effectiveness. Finally, a mass distributed email should be used to remind RIT commuters of the increased danger of a deer-vehicle collision during certain times of the year that correlate with the data collected in Tables 3 and 4. The emails should also include a reminder for commuters of the increased risk of DVC occurrences every day during low light conditions.

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APPENDIX I

RIT Deer Study Data Sheet
Observer’s Name:_________________________________

Date:______________   Time:_________________

Number of Deer Observed:____________

Fawn________   Doe__________   Buck__________

Location:____(also plot on map)

Surrounding Vegetation: Lawn   Meadow   Forest
Other____________
Weather Conditions: Sunny   Overcast   Raining
Other____________

Please Return Sheets (or Direct Questions to):

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