8-2010

Spatial and temporal relationships between deer harvest and deer-vehicle collisions at Oak Ridge Reservation, Tennessee

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To the Graduate Council:

I am submitting herewith a thesis written by Amanda Marie Pierce entitled "Spatial and temporal relationships between deer harvest and deer-vehicle collisions at Oak Ridge Reservation, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Lisa I. Muller, Major Professor

We have read this thesis and recommend its acceptance:

Graham J. Hickling, Neil R. Giffen

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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SPATIAL AND TEMPORAL RELATIONSHIPS BETWEEN DEER HARVEST AND DEER-VEHICLE COLLISIONS AT OAK RIDGE RESERVATION, TENNESSEE

A Thesis Presented for the
Master of Science Degree
University of Tennessee, Knoxville

Amanda Marie Pierce
August 2010

DEDICATION

I dedicate this thesis and all the time and effort to my parents James and Pat, and my fiancé Chris. You have stood by me as I grumbled and growled through the years and years of data. I owe my success to your continued support and never-ending encouragement. I love you all dearly for sticking by my side as I have pursued my goal. Thank you for raising me in such a way that I appreciate the value of hard work and understand that if you want to get a big job done, it's going to be a lot of hard work, but well worth it in the end.

And lastly, I dedicate this thesis to all the deer who have sacrificed their lives over the past 30+ years to enable me to have such a fantastic data set. I hope that this information can be used to keep the population at a healthy level, and keep the roadkill numbers to a minimum.

ACKNOWLEDGEMENTS

First and foremost I would like to extend a heartfelt THANKS to Dr. Lisa Muller, who agreed to take me on as a student while I was also working full time – I now know this can be *QUITE* a challenge. I truly appreciate your upbeat attitude and positive nature, even when I began to doubt myself – that has meant more to me than you could understand.

I would also like to thank Jim Evans of the Tennessee Wildlife Resources Agency and Neil Giffen of the Oak Ridge National Laboratory. You all provided the endless supply of data and support that made the project what it has become. I appreciate your long-term knowledge of the wildlife management program on the Oak Ridge Reservation and your willingness to share that information. I'd have been nowhere without you guys during this project. I would also like to thank Pat Parr, Oak Ridge Reservation Natural Resources Manager, for her support on this study. Thanks to the Department of Energy for providing the funding to make the going through the data a little easier. I would like to specifically thank David Page from the Department of Energy for his support.

Thank you to Dr. Graham Hickling for the input when I came asking for advice, and being willing to take me on as a grad student in the beginning.

A special thanks to Ann Froschauer who spent countless nighttime hours outside of her own forty-hour workweek reviewing and entering the historical data sets. I can put no value on the time you saved me in getting the final product where it is today.

I would also like to thank Phillip Allen in the Biosystems Engineering department for being my GIS mentor. Again – another who I'd be nowhere without. Thank you Phillip for your seemingly ENDLESS knowledge of the ArcView software and its capabilities.

Thank you also to Jason Henning who was able to make sense of my statistics when I couldn't at first. Your ability to manipulate the statistics in SAS and Excel is far and above all others – and I couldn't have done it without you!

To Catherine Nyiniyi, whom I ran to for last minute statistics help, thanks for dropping what you were doing to help a friend in statistical need.

Lastly, but certainly not least, I thank Dr. Vince Pantalone for being an exceptional boss who allowed me to pursue my master's degree from a field of study other than his own. Thank you for allowing me to complete work tasks around my class schedule, and being continually supportive of my education.

ABSTRACT

The Department of Energy Oak Ridge Reservation (ORR) and the nearby adjoining City of Oak Ridge, Tennessee had experienced a rise in deer-vehicle collisions (DVCs) to the point where safety for employees and residents became a concern. I investigated the effect of hunting, land cover, road mileage, season, lunar phase, sex, and change in traffic patterns that coincide with work shifts on DVCs from 1975 - 2008. The study area was divided into grids of 1.5 km^2 each for administration and data recording by managing agencies. Statistical analyses were performed on the ORR (121 grids) and GIS analyses were performed on the entire study area that included ORR and the city of Oak Ridge (190 grids). The number of DVCs in 1975 was 16 and reached a high of 273 in 1985. Therefore, managers initiated a hunting program in 1985 and recorded deer harvest numbers by grid each year. Deer harvest has been occurring from 1985 until present, except when hunting was cancelled due to security concerns after the September 11 terrorist attacks in 2001. By 2008, the number of DVCs had decreased to 100 per year. When hunting first started in 1985, they harvested 926 deer. By 2008, that number was down to 481. I used GIS mapping to record DVCs, deer harvest per grid, landcover types, and mileage per grid to determine factors affecting DVCs on the smaller landscape. Following the initiation of annual hunts, both the annual deer harvest and the number of DVC's have fallen, presumably because the overall deer population

has declined from high pre-hunting levels. Deer harvest appears to be related to landcover characteristics, as a higher percentage of deer were harvested from forested areas than from other landcover types, as forested areas were most prominent. The months of October, November, and December had the highest DVC numbers. Increased traffic during starting and leaving shift times seem to increase the number of DVCs as well. Lunar phases only seem to significantly increase DVCs during the gestation and fawning seasons. Does are involved more frequently with DVCs than bucks during gestation, fawning and prerut, but not during the rutting season. I expect managers can use this data to guide intensive local management aimed at reducing DVCs by increasing the number of deer harvested and increased public education.

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CHAPTER 1

INTRODUCTION

Deer-vehicle collisions (DVCs) with white-tailed deer (*Odocoileus virginianus*) have risen significantly in the United States in the past 40 years. Since the 1970s, the annual number of DVCs in the United States has increased from approximately 200,000 to an estimated 500,000 in 1995 (Malhotra et al. 2000), and to 1.5 million in 2008 (Mastro et al. 2008). In 1995 the National Safety Council estimated such collisions cost more than $125 million in medical expenses, $940 million in vehicle repairs, and $350 million in wildlife loss (Malhotra et al. 2000). In 2008, the nationwide estimated property damage cost per road kill was $2,950 per DVC, up 2.5 percent from 2007 (State Farm 2008) which costs insurance companies, drivers and state and federal agencies nearly $3 billion annually (Haglund and McAleese 2004).

JUSTIFICATION

There is limited information on the ecology and distribution of DVCs along non-interstate roadways, and even less on the physical roadside characteristics (Bashore et al. 1985). Long-term data on the management and control of the white-tailed deer population on the Oak Ridge Reservation (ORR), Tennessee provides an ideal opportunity to evaluate factors affecting the number of these DVCs due to special security issues, administration, and long-term monitoring.

OBJECTIVES AND HYPOTHESES

This project was designed to understand the spatial and temporal effects of hunting and land use on DVCs.

The objectives of my study were to:

1. Determine potential relationships among space, time, deer harvest, and habitat parameters with DVCs from 1975 – 2008 at ORR.
2. Use this information to help manage the ORR deer hunting for decreased DVCs.

My research hypotheses were that:

1. DVCs would decrease as hunting increased.
2. DVCs would increase in areas that had a higher road mileage.
3. DVCs would be affected by surrounding land use.
4. DVCs would be higher during the fall rut period (approximately late September through early December).
5. DVCs would be affected by lunar phases, sex of the deer, and traffic volume changes related to work shift changes of area employees.

LITERATURE REVIEW

Factors known to affect deer-vehicle collisions

Mastro et al. (2008) found that an estimated 1.5 million DVCs occurred annually and 29,000 of those involved human injury. Conover (1995) estimated that 211 fatalities occurred each year. Loss of human life, physiological trauma to victims and their families, absence from work, loss of wildlife, and negative aesthetic values from decaying carcasses and the cost of removal cannot be calculated (Puglisi et al. 1974; Riley and Marcoux 2006). Environmental factors and human activities have been shown to reduce DVCs. Although environmental factors are often difficult to alter, human activities may be changed through education.

Deer density.— In Pennsylvania, Bashore et al. (1985) reported DVCs were more likely to occur in areas of high deer density. Between 1969 and 1982, enforcement officers with the Pennsylvania Game Commission, reported 313,338 deer were killed by vehicle collision in Pennsylvania. More of the DVCs occurred in areas with high deer densities and extensive highway systems. In Arkansas, Farrell and Tappe (2007) found DVCs increased as deer density increased at the county level.

Landcover type.— In Vigo County, Virginia, Gonser et al. (2008) found increasing DVCs between 1999 and 2003 despite the fact that vehicle registrations and traffic volumes remained static. Planted and cultivated land, and not forested areas, were associated with increased DVCs. Planted and cultivated land provided deer with an important food source, whereas forests supplied primarily cover.

Season.— Puglisi et al. (1974) found significantly higher DVCs in November and December than other months in Pennsylvania. This peak of DVCs was correlated with fall mating and hunting seasons. In Michigan, Reilly and Green (1974) found a slight increase in DVCs associated with fawning season in April and May. On the Savannah River Site in South Carolina, between 1990 and 1995, Novak et al. (1999) also found a spring increase with 62% of DVCs being females. A second peak in November corresponded with the fall mating season where 71% of the DVCs were males (Novak et al. 1999).

Hunting pressure.— In contrast to harvest removing animals and possibly reducing DVCs, hunting may cause deer to move more frequently, leave their home range, and increase the likelihood of a DVC. The peak rut and hunting season usually coincide and therefore effects on DVC are confounded. Sudharsan et al. (2006) examined DVCs at 28, 14, and 7 days prior to and after opening day (November 15) of hunting season in Michigan. Peak rut occurred the first 2 weeks of November in Michigan. The peak of DVCs occurred on opening day then decreased by 25% during the first week of the hunting season. It was estimated that 10-15% of the deer herd was removed in the first week of hunting season, leaving less deer available to be hit, and could have contributed to the 25% decrease in DVCs. This trend could be due to the higher number of successful hunters who participate on opening day and the first week of the season and remove part of the deer population. Riley and Marcoux (2006) found a pronounced increase in DVCs in Michigan from October through January 2001-2003 that corresponded with the fall hunting season. Therefore hunting season, which extended beyond the rut, could have caused the increase in DVCs.

Time of day.— In Finland between 1989 and 1997, the Finnish National Road Administration reported 21,887 DVCs with white-tailed deer and moose (*Alces alces*; Haikonen and Summala 2001). There was a peak in DVC activity 1 hour after sunset across all seasons, but a higher peak in the fall. In the fall, 12.5 % of DVCs occurred ±15 min from 1 hour after sunset. This fall peak was 30 times higher than the normal seasonal daytime vehicle collision rate for white-tailed deer. There was also an increase in DVCs within the hour before sunrise, but not as extensive as after sunset. On the Savannah River Site in South Carolina, 50% of all collisions occurred within 2 hours on either side of sunrise, and 30% occurred within 2 hours on either side of sunset (Novak et al. 1999).

Human population density.— As the human population increases, and the number of vehicles on the road increases, you would expect the chances of a DVC to increase. Farrell and Tappe (2007) found higher human population densities and traffic volume significantly increased DVCs at the county level in Arkansas. Higher vehicle traffic was 2.5 times more likely to predict DVC than landcover type.

Speed and traffic volume.— Solomon (1964) developed a curve which illustrated that as speed increased or decreased from the average speed limit by up to 40mph, the possibility of a collision increased exponentially. In West Virginia, increased vehicle speed reduced driver reaction time, which in turn, increased the chances of being involved in a DVC (Green 2000). The element of surprise slowed driver reaction time depending on speed. Bashore et al. (1985) found posted speed limits were negatively correlated with DVCs. However, deer appeared to cross less frequently where actual vehicle speed was higher regardless of posted speed. In the Canadian Rocky Mountains, traffic volume may have more of an effect on DVCs than speed, as increased volume creates a barrier effect, preventing deer from crossing due to reduced habitat permeability (Alexander et al. 2005). Bissonette and Kassar (2008) could not find any relationships between DVC occurrence and posted speed limit or traffic volume after analyzing data on 24,210 DVCs in Utah from 1992 to 2002. There were too many dimensions (i.e. actual driver speed, curved roads and line-of-sight, topographic relief, and vegetative features) that were ever-changing along sections of the roadway.

Lunar phases.— Lunar phase effects on deer have been a much debated topic between hunters and scientific researchers. Hunters suggest that deer are more active during the full moon, while research suggests that lunar phases have no effect on deer behavior. A study by Henke (1997) in southern Texas looked at when deer were utilizing feeders, and found no significant relationships between lunar phases and deer feeding times. In a contrasting study, deer in Washington were observed at a salt-lick area and showed a correlation between periods of bright moonlight and occurrence of deer (Buss and Harbert 1950). The peak number of deer occurred on the full moon, and the lowest numbers occurred on or nearest the new moon.

CHAPTER 2 – SPATIAL AND TEMPORAL RELATIONSHIPS BETWEEN DEER HARVEST AND DEER-VEHICLE COLLISIONS AT OAK RIDGE RESERVATION, TENNESSEE

INTRODUCTION

Each year in the United States there are an estimated 1.5 million deer-vehicle collisions (DVCs) involving white-tailed deer (*Odocoileus virginianus;* Mastro et al. 2008). The 2008 nationwide estimated property damage cost per road kill was $2,950 per DVC (State Farm 2008). While we can put a number on property damage, it is much harder to put a price on the societal costs, which may include human death (211 per year; Conover 1995), human injury (29,000 per year; Conover et al. 1995), absence from work, and physiological trauma to victims and their families (Riley and Marcoux 2006).

There are several factors which have been shown to affect DVCs including landcover type (Gonser 2008), season (Puglisi et al. 1974, Reilly and Green 1974), time of day (Haikonen and Summala 2001), human population density (Farrell and Tappe 2007), hunting pressure (Sudharsan et al. 2006), and speed (Green 2000 and Solomon 1964). Wildlife managers may only have the ability to affect harvest to reduce DVCs and educate the public on the other factors potentially contributing to increased risk of DVC.

Oak Ridge Reservation (ORR) was originally acquired in 1942 for the construction of the atomic bomb production facilities that were part of the U.S. Army's Manhattan

Project (Lee et al. 1988). The land was later designated as a Wildlife Management Area (WMA) in 1984 through a cooperative agreement with the Tennessee Wildlife Resources Agency (TWRA) and the Oak Ridge Operation of the U.S. Department of Energy (DOE; Giffen et al. 2007). The cooperative agreement between these agencies required that the area be managed and governed by federal laws, executive orders and DOE directives that included, but were not limited to the Fish and Wildlife Coordination Act, the National Environmental Policy Act, and the Sikes act (Giffen et al. 2007).

DVCs undoubtedly began occurring in the area as soon as roads were established; however the problem was not of sufficient concern for records to be kept until the late 1960s. The first reported DVC on the ORR was in October 1969. Information on DVCs has been recorded since 1975 and mapped since 1977 to track damage to vehicles and people and assess the possibility of contaminated deer being picked up and consumed (J. Evans, Tennessee Wildlife Resources Agency, personal communication). Radioactive cesium and strontium have been reported on wildlife from ORR (Garten 1995). The special security issues, governance, and long-term monitoring at ORR provide an ideal setting to study spatial and temporal relationships between deer harvest and DVCs. Shift-related road traffic has been monitored on some roads at ORR. Data obtained from DVCs indicated that deer population growth was high since 1969 and habitat destruction was likely to occur if the trend continued. Therefore, a reservation-wide annual hunting season was established for the public in 1985 (Lee et al.1988).

The objectives of my study were to determine relationships among space, time, deer harvest, and habitat parameters with DVCs at ORR from 1975 – 2008. I expect that wildlife managers can use this information to facilitate deer hunting to decrease DVCs on ORR.

STUDY AREA

The ORR is 13,400 ha of federally owned land in Anderson and Roane Counties in eastern Tennessee (Appendix A, Fig 1). The ORR lies in central east Tennessee along the western edge of the ridge and valley physiographic province that is between the Cumberland Mountains to the northwest and the Great Smoky Mountains to the southeast (Lee et al. 1998). Elevation on the ORR ranges from 230 - 410 m above sea level (Lee et al.1998). The area is surrounded on its south, west and east sides by Melton Hill and Watts Bar Lakes. The Clinch River and the city of Oak Ridge are located north of ORR (Flynn 1976).

The ORR is composed mostly of contiguous native eastern deciduous forests. About 70% of the ORR is in forest cover and 20% in transitional areas such as old fields, agricultural areas, roadsides, and utility corridors (USGS 1992). Giffen et al. (2007), reported < 2% of the Reservation is in open agricultural fields (Fig 1).

The ORR includes the industrial sites of the Oak Ridge National Laboratory (ORNL), the Y-12 National Security Complex, and the East Tennessee Technology Park (ETTP) and former K-25 site (Fig 1,). ORNL and Y-12 were established in 1943 as a part of the World War II Manhattan Project to create a method for producing and separating plutonium (DOE 2010). During the 1950s and 1960s, ORNL became an international center for the study of nuclear energy and related research (ORNL 2009). The former K-25 site was once used to separate uranium-235 from uranium-238.

Deer hunts have been conducted on the ORR since 1985. Deer seasons were normally 3 2-day hunts (Saturday and Sunday) in October, November, and December, and bag limits were typically 2 deer, with 1 antlered. In 2003, managers implemented antler restrictions to promote quality deer management (QDM) and limited buck harvest to those animals with at least 4 antler points on 1 side or a 38.1 cm (15 inch) outside antler spread. These restrictions promoted larger antlered bucks and encouraged a higher doe harvest. The antler restrictions were dropped in 2007 to increase overall harvest.

METHODS

Information on each DVC was recorded from 1975 through 2008 by ORR wildlife managers. Data collected included date, time, location by grid, and biological information on the deer (sex, age, and pregnancy status) where applicable.

GIS Analysis

Tennessee Valley Authority (TVA) created maps for DOE that included 190 1.5-km² administrative grids based on 1927 North American datum (NAD27). Habitat data was obtained from the U.S. Geological Survey (USGS) online seamless map server (USGS 1992). Habitat types were broken down into 5 cover types: forest (deciduous and evergreen), field (open areas in grasses or agricultural crops), water (creeks, rivers, and lakes), developed (industrial areas within ORR), and barren (waste sites that have been covered with concrete or other solid materials). Road data for the ORR was obtained from 2006 ORNL files (S. Cotter, ORNL, Personal communication) and the rest of the study area from the National Atlas and Bureau of Transportation Statistics roads files on the USGS seamless map server (USGS 1992). I conducted spatial analysis on the ORR and city of Oak Ridge with ArcMap 9.2 (ESRI, Redlands, California, USA) and georeferenced data with the TVA grid maps. I imported the number of DVCs and hunter harvest for each grid over time into the georeferenced maps.

Road Classification

Road data from 2006 was classified in 3 categories based on estimated traffic volume and speed for each grid (Fig 2). I assigned grids as high-traffic-high-speed (HTHS) when there were ≥ 0.5 km of 4-lane highways and other major roads within the grid and speeds were 72.4 km/hour (45 miles/hour) or more. I assigned, high-traffic-low-speed (HTLS) to the roads inside of the Y-12 and ORNL facilities within ORR where there was a high traffic volume because of employees traveling to and from work, but speed limits were ≤ 32.1 km/hr (≤ 20 miles/hour). I assigned low-traffic (LT) to roads that were considered secondary, where speed limits were generally lower (48.2-72.4 km/hr, 30-45 miles/hour) but not necessarily policed for speed. Roads that had more than 0.5 km of different types of roads were classified as the highest traffic and highest speed category.

Statistical Analysis

I used proc GENMOD (SAS Institute Inc., Cary, North Carolina, USA) for Poisson regression analysis using the repeated measures model for robust standard errors to determine the influence of harvest numbers, road distance, and landcover category on total DVCs (1985-2008). Separate analyses were run for the three road categories with a log/link function for the years after deer harvest began (1985-2008). Analysis was broken down by road group to estimate traffic volume and speed. I only used the 121 grids in ORR for analysis, as hunt data was not recorded outside those grids and DVC data was not consistently recorded. Grids within the ORR that were not hunted were assigned zero annual harvest for the analysis. I used total counts for each year (1985-2008) by grid for DVC and harvest. Habitat data was from 1992, and was assumed to have been constant over the years. Poisson regression was used because DVC number was discrete count data. I undertook a simple analysis (mean, standard deviation, minimum, and maximum) of the factors that were used in the ProcGENMOD procedure.

I used proc CORR (SAS Institute Inc.), to obtain a matrix of correlations among all the variables used in the regression model (i.e., mean DVC, mean harvest, road distance, and the five landcover categories.) Again, the analysis was repeated for each road category. I used means to calculate annual accident and harvest rates since the values for the other parameters were constant across years.

I used Proc GLM (SAS Institute Inc.) with Tukey's studentized range test to determine the effect of month on DVCs before hunting (1975-1984) and after hunting (1985-2008). Lunar phases (first quarter, full moon, last quarter and new moon) were obtained from the NASA (2007). Shifts for workers at ORR were broken down into 5 categories based on work schedules: start (0500 hours to 0900 hours), daytime (0900 hours to 1500 hours), leaving (1500 hours to 1900 hours), late evening (1900 hours to 0000 hours) and overnight (0000 hours to 0500 hours). This was done to predict traffic volume changes during the day. Seasons were based on deer biology as described by Kjaer (2007) where the gestation period was 1 January - 14 May 14, fawning was 15 May 15 – 31 August, prerut was 1 September 1 – 31 October, and the rut period was considered from 1 November – 31 December. I used a chi square test (SAS Institute Inc.) to evaluate DVC occurrence by lunar phase, shift, and sex of deer for seasons.

RESULTS

From 1975-2008, 4,643 DVCs occurred at the ORR. The number of DVCs peaked at 273 in 1985, which was the year when hunting began. Thereafter DVCs generally declined to 100 by 2008 (Fig 3). The 1985 hunt reduced the herd by 926 deer (Tennessee Wildlife Resources Agency 1986); thereafter the annual harvest trended downward in most years. Due to the terrorist attacks on September 11, 2001, hunting was suspended and no deer were harvested for the year, and DVCs increased from 102 in 2000 to 148 and 160 in 2001 and 2002 respectively. DVC numbers slowly decreased in 2003 to 2006 from 152, 129, 152, and 111 respectively (Fig 3). Until 2003, buck harvest was higher than doe harvest (Fig 4). Buck harvest remained below doe harvest until 2007, when antler restrictions were removed. During January to September DVCs ranged from 254 to 322 per month across all years. In the fall, mean monthly DVCs increased significantly to 486 in October, 864 in November, and 530 in December (Fig 5). These three months all had significantly higher DVC numbers than other months ($P \leq 0.0001$).

Prior to hunting (1975-1984), mean DVCs by grid ranged from 0-7 (Fig 6A). Hunting began in 1985 and 926 deer were harvested (Fig 6B). There was an increase in mean number of DVCs by year for *some* grids from 1986-2000, showing areas of higher DVC intensity (Fig 7A). Hunter harvested deer decreased after the initial year of hunting (Fig 7B). Intensity of DVCs and harvest changed from 2002-2006 with strict security measures established after September 11, 2001 (Fig 8). Increased speed enforcement, road construction, and cancellation of antler restrictions in 2007-2008 affected DVCs as well as hunter harvest numbers (Fig 9). The number of DVCs and the number of deer harvested each year are in Figures 11-44.

Harvest and road distance were positive predictors of DVCs in HTHS and LT road groups. In HTLS, they were inversely related (Table 1). Forest was inversely related to DVCs in all road categories. The other habitat variables (water, developed, and field) were all inversely related to DVC except water in HTLS. Barren was found to be linearly dependent with field, and, therefore, no analysis was reported. However, harvest rate was positively correlated with forest and negatively correlated with road distance, developed, and field in HTHS and LT road groups (Tables 2 and 4). The same trends occurred with the HTLS group but did not reach significance (Table 3). There were no significant correlations with harvest and water in any road group. No significant correlations between harvest and road distance or the landcover types occurred in the HTLS road group. The result of the simple statistics ran on these parameters is shown in Table 5.

Lunar phase affected DVCs during gestation and fawning (Table 6). The highest number of DVCs occurred during the full moon in the gestation season (29.48 %) and in the last quarter during the fawning season (33.22 %, Table 6). The highest occurrence of DVCs occurred during the start shift time (0500 hours to 0900 hours) for all seasons (Table 7). The number of female deer killed by vehicle collision was higher than males for all seasons except for during the rut, which showed a higher frequency overall, with 125 unknowns (22.64%), 168 females (30.43%), and 259 males (46.92%) (Table 8).

DISCUSSION

Bashore et al. (1985), in Pennsylvania, found DVCs increased with deer density. Hunting decreased the herd size by 926 deer in 1985 and reduced the number of deer susceptible to vehicle collision. Jenks et al. (2002) analysis of ORR DVCs showed deer mortality from vehicle collisions decreased by 50 % in 5 years from 1985 to 1994 and thought deer populations stabilized to 60 % of their pre-hunted densities during this period. From 1994 on, DVCs fluctuated between 187 at the highest in 1996 to 100 at the lowest in 2008 (Fig 3). I did not have density data, but also found DVCs remained relatively stable following hunting.

After the terrorist attacks on September 11, 2001, hunting was suspended and no deer were harvested for the year. DVCs increased from 102 in 2000 to 148 in 2001 and to 160 in 2002indicating that deer harvest played an important role in reducing the number of DVCs on the ORR. It was not until 2006 before DVCs dropped to previous levels.

Occurrence of DVCs showed a positive relationship with deer harvest in the HTHS and the LT groups (Table 1). The HTLS group only covered 7 grids and had limited hunting. The positive relationship with harvest number and DVCs was likely related to deer density. Harvest number was also positively correlated with forested areas and negatively correlated with road distance and developed areas in the HTHS and LT groups, (Tables 2 and 4). These same correlations occurred in the HTLS road group, but were not significant (Table 3). In my study area, deer are more likely to be found in forested areas away from roads and developed areas, as there are more forested areas in the study area than other land cover types.

Novak et al. (1999) suggested harvesting deer from areas not previously hunted to remove more deer and decrease DVCs. In 2007-2008, wildlife managers opened areas previously not hunted to increase harvest. Antler restrictions were cancelled in 2007, which allowed for a more liberal buck harvest. The higher buck harvest may have contributed to lower DVCs in 2007 and 2008. However for continued declines in DVCs, doe harvest may need to be increased.

Gonser et al. (2008) found that DVCs were more likely to occur on planted and cultivated land, and deer used forested areas primarily as cover. In my study area, forest had a negative relationship with DVCs in all grids. However, forests comprised the largest land cover (70%; USGS 1992) and< 2 % of my study area was in open agricultural fields (Giffen et al. 2007). Therefore, deer had to primarily use forests for all needs.

Alexander et al. (2005) found that traffic volume decreased DVC numbers, as increased traffic volume created a barrier effect and prevented deer from crossing. However, this contradicts my research, where roads did not appear to have a high enough traffic volume to create a barrier effect, and do not stop DVC from occurring. In the HTHS and LT road groups, there was a positive relationship between road distance and DVCs (Table 1). In HTLS, there was more development around the roads and less deer habitat which lead to a negative relationship between road distance and DVCs (Table 1).

Across all the years, more DVCs occurred in October, November, and December (Fig 5). This is confounded by evidence that hunting pressure may increase DVC likelihood (Sudharsan et al. 2006) because deer may be moving more frequently, but may also be moving due to rutting activity, which coincides with hunting season. In my study, 3 hunts were normally scheduled during each season; one in each of October, November, and December. From the positive relationships between DVCs and harvest numbers in the HTHS and LT road groups, I believe that harvest may have had an effect on decreasing DVC occurrence, taking deer out of the population and decreasing the likelihood of being involved in a DVC. A study from Riley and Marcoux (2006) found that hunting season extended beyond rutting season, and may have had an effect on the rise of DVCs. On the ORR, the peak of rutting season occurs between November 10 and December 10, confounding this explanation (J. Evans, Tennessee Wildlife Resources Agency, personal communication).

There were significant differences in DVCs by lunar phase during fawning and gestation seasons (Table 6). Across all seasons, most DVCs occur during the start shift (0500 hours to 0900 hours) possibly due to the increased traffic and crepuscular behavior of deer (Miller et al. 2003) (Table 7). More males than females were involved in DVCs during the rut period, although both sexes showed an increase in DVC occurrence during this time. The increase in DVCs during the rut is possibly due to increased movement for both males and females during breeding (Kolodzinski et al. 2010).

MANAGEMENT IMPLICATIONS

Although deer density was not measured directly, it appears to be the main factor affecting DVCs at Oak Ridge and ORR. Current harvest appears to be maintaining level numbers of DVCs. Fewer deer were harvested with archery equipment than guns and most of the deer were harvested in forests, the predominant landscape type. Perhaps a substantial increase in harvest would facilitate a herd reduction and reduction of DVCs. Harvest could be increased by increasing hunter quota or by extending the hunts at ORR to 3 days. However, adding a fourth 2-day hunt to the season, increasing the quota, or number of hunters drawn for each hunt may be more beneficial to increase hunter effort. Increasing hunter quota could be effective; however, increased hunters in a particular area can cause safety issues and defeating the purpose. Extending the size of the area that can be hunted is another option managers could consider. Increasing the daily bag limit on deer would be an option for increasing harvest. Hunters are now allowed to kill two deer, no more than one antlered. Increasing the limit to *two* antlerless and one antlered may reduce the does, further slowing potential for herd growth. Increasing gun hunting may help reduce deer numbers, but may not be the most effective solution.

Managers may also alter human behavior by educating the public about the fall hunting and breeding seasons in October, November, and December which carry a higher likelihood of being involved in a DVC.

Appendix B (Fig 44 and Table 9) includes a DVC intensity map, and hunting information for each grid. Areas with higher DVCs may benefit from increased harvest. Non-hunted areas with high DVCs would benefit from adding hunter harvest. If security issues are of concern in these areas, perhaps hunting could be restricted to badged ORR personnel.

The highest numbers of DVCs (28-45/grid) from 2004 to 2008 occurred in the grids E15, F14 and F15. These grids include the eastern end of Bethel Valley road, Scarboro Road, Commerce Park, and the southern end of South Illinois Avenue. Since the intersections of Scarboro Road at Bethel Valley road and South Illinois Avenue at Bethel Valley road are prominent thoroughfares for most ORR employees, I believe that the use of enhanced signage would be beneficial. The signs should include flashing yellow lights or strobes as people have become complacent with the typical deer-crossing triangle. Another option for these areas would be to decrease speed limits.

Due to the crepuscular behavior of deer, DVCs occur more often at dawn and dusk, specifically at the start of the work day. Educating employees of this danger, and occasional friendly reminders could help increase awareness of the situation and possibly prevent some DVCs.

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APPENDICES

APPENDIX A

Table 1. Poisson regression analysis to determine potential effects of deer harvest, road distance, and landcover on deer-vehicle collisions at the Oak Ridge Reservation (ORR), Tennessee from 1985-2008 by road category. Hunting began in 1985.

Road Category[a]	Parameter[b]	DF	Estimate	Std. Error	Wald 95% Conf. Limits		Chi Square	Pr > ChiSq
	Intercept	1	16.6836	2.7188	11.3549	22.0124	37.65	<.0001
High –	**Harvest**	1	0.0264	0.0031	0.0205	0.0324	74.96	<.0001
Traffic-	**Road Distance**	1	0.0002	0.0000	0.0002	0.0002	169.25	<.0001
High -	**Forest**	1	-0.1655	0.0274	-0.2191	-0.1118	36.48	<.0001
Speed	**Water**	1	-0.2276	0.0283	-0.2829	-0.1722	64.87	<.0001
(No. of	**Developed**	1	-0.2287	0.0285	-0.2846	-0.1729	64.45	<.0001
grids = 49)	**Field**	1	-0.1581	0.0280	-0.2130	-0.1032	31.89	<.0001
	Barren	0	0.0000	0.0000	0.0000	0.0000	.	.
	Scale	0	1.0000	0.0000	1.0000	1.0000		
	Intercept	1	110.7334	13.6601	83.9601	137.5067	65.71	<.0001
High-	**Harvest**	1	-00643	0.0309	-0.1249	-0.0037	4.32	0.0377
Traffic-	**Road Distance**	1	-0.0005	0.0001	-0.0007	-0.0003	25.77	<.0001
Low-Speed	**Forest**	1	-1.0949	0.1360	-1.3614	-0.8284	64.84	<.0001
(No. of	**Water**	1	9.1553	1.1424	6.9162	11.3943	64.23	<.0001
grids = 7)	**Developed**	1	-0.9722	0.1061	-1.1801	-0.7642	83.96	<.0001
	Field	1	-1.2940	0.1626	-1.6127	-0.9753	63.33	<.0001
	Barren	0	0.0000	0.0000	0.0000	0.0000	.	.
	Scale	0	1.0000	0.0000	1.0000	1.0000		

Table 1. Continued

Road Category[a]	Parameter[b]	DF	Estimate	Std. Error	Wald 95% Conf. Limits		Chi Square	Pr > ChiSq
	Intercept	1	3.0283	1.6098	-0.1268	6.1835	3.54	0.0599
	Harvest	1	0.0231	0.0062	0.0109	0.0353	13.82	0.0002
Low-Traffic (No. of grids = 65)	**Road Distance**	1	0.0003	0.0000	0.0002	0.0003	62.74	<.0001
	Forest	1	-0.0445	0.0163	-0.0764	-0.0126	7.45	0.0063
	Water	1	-0.1212	0.0195	-0.1595	-0.0830	38.62	<.0001
	Developed	1	-0.1141	0.0198	-0.1528	-0.0754	33.35	<.0001
	Field	1	-0.0958	0.0175	-0.1301	-0.0615	29.99	<.0001
	Barren	0	0.0000	0.0000	0.0000	0.0000	.	.
	Scale	0	1.0000	0.0000	1.0000	1.0000		

[a]Road category:

HTHS - 4-lane highways and other major roads with ≥ 0.5 km within the grid and speed limit of 72.4 km/hour (45 miles/hour) or more

HTLS - roads inside of the Y-12 (the National Security Complex on the ORR) and Oak Ridge National Laboratory facilities within ORR where speed limits were ≤32.1 km/hour (≤ 20 miles/hour) or less

LT - secondary roads where speed limits were generally lower (48.2-72.4 km/hour, 30-45 miles/hour)

[b]Parameter Estimates:

Harvest – mean number of deer harvested from 1985-2008 by grid
Road distance – number of meters of road per grid (1992)
Forest - deciduous and evergreen (1992)
Water - creeks, rivers, and lakes (1992)
Developed - industrial areas within Oak Ridge Reservation (1992)
Field - open areas in grasses or agricultural crops (1992)
Barren - waste sites that have been covered with concrete or other solid materials (1992) These were found to be aliased due to lack of observations.
Scale – this parameter was held fixed, and indication of no under- or over-dispersion

Table 2. Pearson Correlation Coefficients to determine potential relationships among deer vehicle collision (DVC) rate, harvest rate, road distance, and landcover in the high-traffic-high-speed (HTHS) classification (49 grids) at the Oak Ridge Reservation, Tennessee from 1985-2008. Hunting began in 1985.

HTHS	DVC Rate	Harvest Rate	Road Distance	Developed	Water	Forest	Field
			For all variables: Pearson Correlation Coefficient P-value				
DVC rate	1.00000	0.20978	-0.03516	-0.13668	-0.37769	0.17468	0.18495
		0.1480	0.8105	0.3490	0.0075	0.2300	0.2033
Harvest rate	0.20978	1.00000	-0.62848	-0.57693	-0.26863	0.70494	-0.39614
	0.1480		<.0001	<.0001	0.0620	<.0001	0.0048
Road distance	-0.03516	-0.62848	1.00000	0.94588	-0.12670	-0.86040	0.47009
	0.8105	<.0001		<.0001	0.3587	<.0001	0.0007
Developed	-0.13668	-0.57693	0.94588	1.00000	-0.17476	-0.83833	0.35251
	0.3490	<.0001	<.0001		0.2298	<.0001	0.0130
Water	-0.37769	-0.26863	-0.12670	-0.17476	1.00000	-0.24340	-0.27220
	0.0075	0.0620	0.3857	0.2298		0.0919	0.8527
Forest	0.17468	0.70494	-0.86040	-0.83833	-0.24340	1.00000	-0.65810
	0.2300	<.0001	<.0001	<.0001	0.0919		<.0001
Field	0.18495	-0.39614	0.47009	0.35251	-0.02722	-0.65810	1.00000
	0.2033	0.0048	0.0007	0.0130	0.8527	<.0001	

[a]Road category:

HTHS - 4-lane highways and other major roads with ≥ 0.5 km within the grid and speed limits of 72.4 km/hour (45 miles/hour) or more

[b]Parameter Estimates:

DVC rate – mean number of deer vehicle collisions by grid from 1985 – 2008.
Harvest rate – mean number of deer harvested by grid from 1985-2008
Road distance – number of meters of road per grid (1992)
Forest - deciduous and evergreen (1992)
Water - creeks, rivers, and lakes (1992)
Developed - industrial areas within Oak Ridge Reservation (1992)
Field - open areas in grasses or agricultural crops (1992)

Table 3. Pearson Correlation Coefficients to determine potential relationships among deer vehicle collision (DVC) rate, harvest rate, road distance, and landcover in the high-speed-low-traffic (HTLS) classification (7 grids) at the Oak Ridge Reservation, Tennessee from 1985-2008. Hunting began in 1985.

HTLS	DVC rate	Harvest Rate	Road Distance	Developed	Water	Forest	Field
	For all variables: Pearson Correlation Coefficient P-value						
DVC rate	1.00000	0.79640	-0.08586	-0.50022	0.07378	0.42519	-0.17586
		0.0321	0.8548	0.2529	0.8751	0.3416	0.7060
Harvest rate	0.79640	1.00000	-0.42462	-0.70814	0.25725	0.57099	-0.00732
	0.0321		0.3423	0.0750	0.5776	0.1806	0.9876
Road distance	-0.08586	-0.42462	1.00000	0.77380	-0.05903	-0.35081	-0.35385
	0.8548	0.3423		0.0418	0.9000	0.2444	0.4362
Developed	-0.50022	-0.70814	0.77238	1.00000	0.27587	-0.84321	0.04131
	0.2529	0.0750	0.0418		0.5493	0.0172	0.9299
Water	0.07378	0.25725	-0.05903	0.27587	1.00000	0.47702	0.54529
	0.8751	0.5776	0.9000	0.5493		0.2791	0.2055
Forest	0.42519	0.57099	-0.50806	-0.84321	-0.47702	1.00000	-0.55479
	0.3416	0.1806	0.2444	0.0172	0.2791		0.1961
Field	-0.17586	-0.00732	-0.35385	0.04131	0.54529	-0.55479	1.00000
	0.7060	0.9876	0.4362	0.9299	0.2055	0.1961	

[a]Road category:

HTLS - roads inside of the Y-12 (the National Security Complex on the ORR) and Oak Ridge National Laboratory facilities within ORR where speed limits were ≤ 32.1 km/hour (≤ 20 miles/hour) or less

[b]Parameter Estimates:

DVC rate – mean number of deer vehicle collisions by grid from 1985 – 2008.
Harvest rate – mean number of deer harvested by grid from 1985-2008
Road distance – number of meters of road per grid (1992)
Forest - deciduous and evergreen (1992)
Water - creeks, rivers, and lakes (1992)
Developed - industrial areas within Oak Ridge Reservation (1992)
Field - open areas in grasses or agricultural crops (1992)

Table 4. Pearson Correlation Coefficients to determine potential relationships among deer vehicle collision (DVC) rate, harvest rate, road distance, and landcover in the low-traffic (LT) classification (65 grids) at the Oak Ridge Reservation, Tennessee from 1985-2008. Hunting began in 1985.

LT	DVC rate	Harvest Rate	Road Distance	Developed	Water	Forest	Field
For all variables: Pearson Correlation Coefficient P-value							
DVC rate	1.00000	0.05508	0.11483	0.05033	-0.23092	0.16683	-0.01214
		0.6630	0.3624	0.6905	0.0642	0.1841	0.3356
Harvest rate	0.05508	1.00000	-0.45147	-0.38989	0.02512	0.44178	-0.40310
	0.6630		0.0002	0.0013	0.8425	0.0002	0.0009
Road distance	0.11483	-0.45147	1.00000	0.92924	0.35103	-0.59317	0.30880
	0.3624	0.0002		<0.0001	0.0041	<.0001	0.0123
Developed	0.05033	-0.38989	0.92924	1.00000	-0.23927	-0.66654	0.19118
	0.6905	0.0013	<.0001		0.0549	<.0001	0.1271
Water	-0.23092	0.02512	-0.36103	-0.23927	1.00000	-0.40658	-0.15903
	0.0942	0.8425	0.0041	0.0549		0.0008	0.2057
Forest	0.16683	0.44178	-0.59317	-0.66654	-0.40658	1.00000	-0.49956
	0.1841	0.0002	<.0001	<0.0001	0.0008		<.0001
Field	-0.12135	-0.40310	0.30880	0.19118	-0.15903	-0.49956	1.00000
	0.3356	0.0009	0.0123	0.1271	0.2057	<.0001	

[a]Road category:

LT - secondary roads where speed limits were generally lower (48.2-72.4 km/hour, 30-45 miles/hour)

[b]Parameter Estimates:

DVC rate – mean number of deer vehicle collisions by grid from 1985 – 2008.
Harvest rate – mean number of deer harvested by grid from 1985-2008
Road distance – number of meters of road per grid (1992)
Forest - deciduous and evergreen (1992)
Water - creeks, rivers, and lakes (1992)
Developed - industrial areas within Oak Ridge Reservation (1992)
Field - open areas in grasses or agricultural crops (1992)

Table 5. Mean deer vehicle collision (DVC), deer harvest, road distance, and landcover types by traffic category at the Oak Ridge Reservation (ORR), Tennessee from 1985-2008.

Road Category[a]	Variable[b]	N	Mean	Std Dev	Min	Max
High-traffic-High-speed (HTHS) (No. grids = 49)	**DVC rate**	49	2.28	1.80	0	6.79
	Harvest rate	49	3.67	4.04	0	13.17
	Road distance	49	6943	5.35	949.40	20549
	Developed	49	12.36	17.10	0	70.20
	Water	49	4.67	8.45	0	28.77
	Forest	49	73.16	22.20	16.46	99.96
	Field	49	9.50	8.80	0	34.14
High-traffic-low-speed (HTLS) (No. grids = 7)	**DVC rate**	7	2.04	2.48	0.17	7.17
	Harvest rate	7	0.85	0.99	0	2.83
	Road distance	7	6681	3751	1867	13873
	Developed	7	16.78	11.31	3.46	39.90
	Water	7	0.12	0.12	0	0.31
	Forest	7	71.57	13.14	50.91	88.85
	Field	7	10.49	6.70	5.01	24.21
Low-traffic (LT) (No. grids = 65)	**DVC rate**	65	0.34	0.67	0	3.042
	Harvest rate	65	3.76	3.58	0	13.67
	Road distance	65	4700	4407	0	18218
	Developed	65	6.47	13.41	0	52.65
	Water	65	7.35	12.05	0	66.62
	Forest	65	78.39	18.11	14.50	100.00
	Field	65	7.40	8.59	0	35.89

[a]Road category:

HTHS - 4-lane highways and other major roads with ≥ 0.5 km within the grid and speed limit of 72.4 km/hour (45 miles/hour) or more

HTLS - roads inside of the Y-12 (the National Security Complex on the ORR) and Oak Ridge National Laboratory facilities within ORR where speed limits were ≤32.1 km/hour (≤ 20 miles/hour) or less

LT - secondary roads where speed limits were generally lower (48.2-72.4 km/hour, 30-45 miles/hour)

[b]Variable:

DVC rate – mean number of deer vehicle collisions by grid from 1985 – 2008.
Harvest rate – mean number of deer harvested by grid from 1985-2008
Road distance – number of meters of road per grid (1992)
Forest - deciduous and evergreen (1992)
Water - creeks, rivers, and lakes (1992)
Developed - industrial areas within Oak Ridge Reservation (1992)
Field - open areas in grasses or agricultural crops (1992)

Table 6. Deer vehicle (DVC) occurrence by lunar phase and season at the Oak Ridge Reservation (ORR), Tennessee from 1985-2008.

Season	Moon	Frequency	Percent	Chi-Square Test for Equal Proportions	
	1st Qtr	125	27.29		
Gestation	Full moon	135	29.48	Chi-Square	9.2664
	Last Qtr	104	22.71	DF	3
	New moon	94	20.52	Pr > ChiSq	0.0260
	1st Qtr	69	23.39		
Fawning	Full moon	69	23.39	Chi-Square	11.5356
	Last Qtr	98	33.22	DF	3
	New moon	5969	20.00	Pr > ChiSq	0.0092
	1st Qtr	69	24.91		
Prerut	Full moon	62	22.38	Chi-Square	1.1949
	Last Qtr	74	26.71	DF	3
	New moon	72	25.99	Pr > ChiSq	0.7542
	1st Qtr	141	25.50		
Rut	Full moon	149	26.94	Chi-Square	1.5533
	Last Qtr	132	23.87	DF	3
	New moon	131	23.69	Pr > ChiSq	0.6700

Season:

Gestation – January 1 – May14
Fawning – May 15 – August 31
Prerut – September 1 – October 31
Rut – November 1 – December 31

Lunar phases obtained from NASA Eclipse Website

Table 7. Deer vehicle (DVC) occurrence by work shift and season on Oak Ridge Reservation, 1975-2008.

Season	Shift	Frequency	Percent	Chi-square test for equal proportions
	Start	178	38.95	
	Day	38	8.32	Chi-square 153.2079
Gestation	Leave	54	11.82	DF 4
	Late	127	27.9	Pr> ChiSq <0.0001
	Night	60	13.13	
	Start	122	41.36	
	Day	36	12.20	Chi-square 98.8475
Fawning	Leave	26	8.81	DF 4
	Late	66	22.37	Pr> ChiSq <0.0001
	Night	45	15.25	
	Start	125	45.13	
	Day	30	10.83	Chi-square 135.9783
Prerut	Leave	28	10.11	DF 4
	Late	71	26.53	Pr> ChiSq <0.0001
	Night	23	8.30	
	Start	219	39.75	
	Day	45	8.17	Chi-square 198.6098
Rut	Leave	126	22.87	DF 4
	Late	124	22.50	Pr> ChiSq <0.0001
	Night	37	6.72	

Season:

Gestation – January 1 – May14
Fawning – May 15 – August 31
Prerut – September 1 – October 31
Rut – November 1 – December 31

Shift:

Start - 0500-0900 hours
Day – 0900 – 1500 hours
Leave – 1500 – 1900 hours
Late – 1900 – 0000 hours
Night – 0000 – 0500 hours

Table 8. Deer vehicle (DVC) occurrence by sex and season on Oak Ridge Reservation, 1975-2008.

Season	Sex	Frequency	Percent	Chi-square test for equal proportions
	.	100	21.83	Chi-square 27.3057
Gestation	F	181	39.52	DF 2
	M	177	38.65	Pr> ChiSq <0.0001
	.	65	22.11	Chi-square 35.6531
Fawning	F	145	49.32	DF 2
	M	84	28.57	Pr> ChiSq <0.0001
	.	71	25.36	Chi-square 9.5595
Prerut	F	113	40.79	DF 2
	M	93	33.57	Pr> ChiSq 0.0084
	.	125	22.64	Chi-square 50.8804
Rut	F	168	30.43	DF 2
	M	259	46.92	Pr> ChiSq <0.0001

Season:
- Gestation – January 1 – May14
- Fawning – May 15 – August 31
- Prerut – September 1 – October 31
- Rut – November 1 – December 31

Sex:
- . – Unknown sex
- F – Female
- M - Male

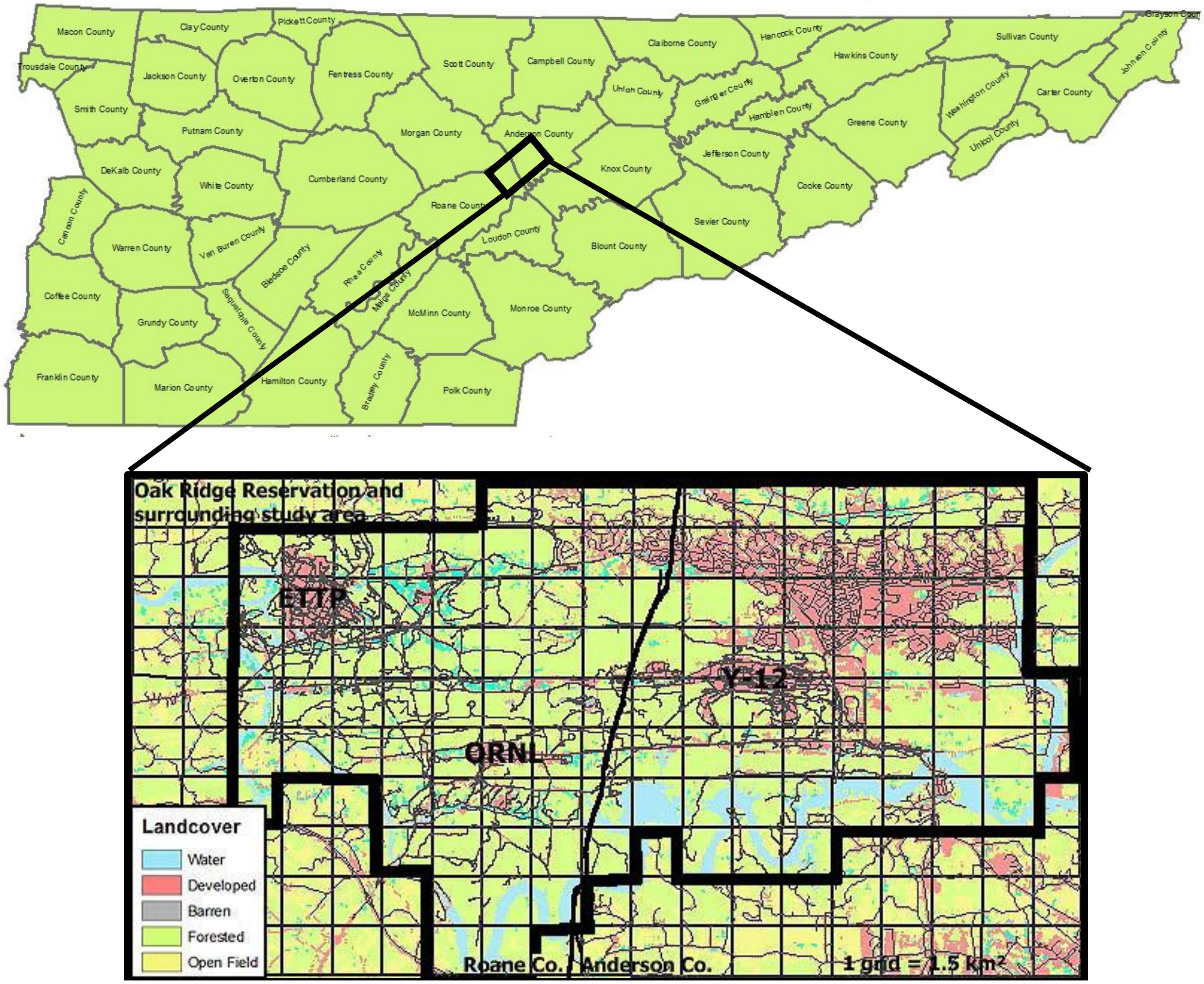


Figure 1. Study area including the city of Oak Ridge and Oak Ridge Reservation in Anderson and Roane County, Tennessee, includes East Tennessee Technology Park (ETTP), Oak Ridge National Lab (ORNL) and Y-12 National Security Complex (Y-12).

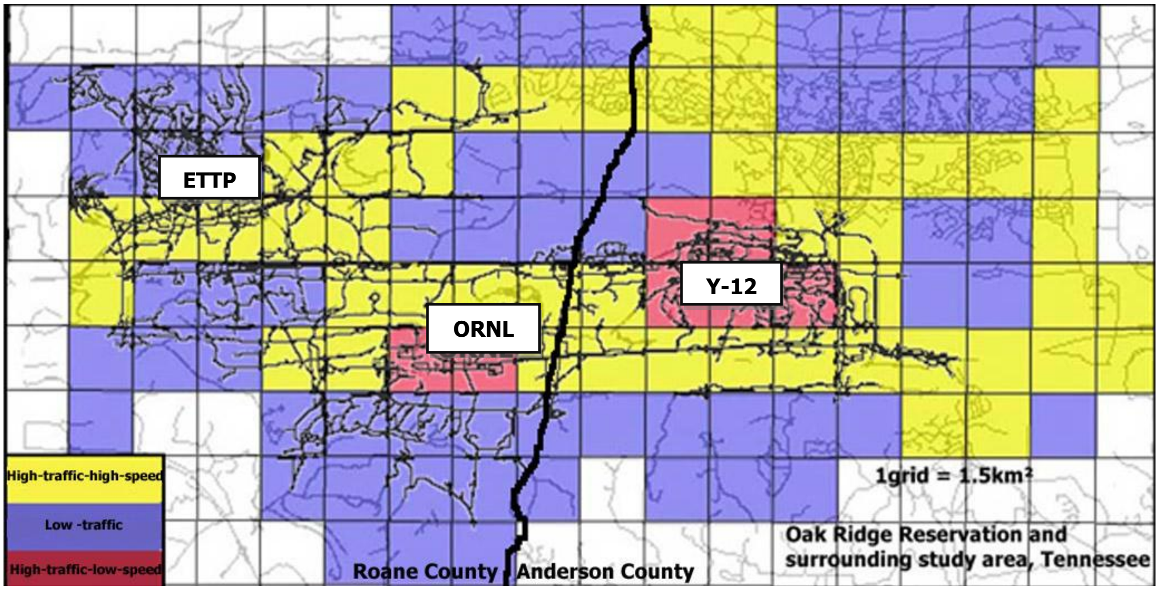


Figure 2. Road groupings for Oak Ridge and the Oak Ridge Reservation, Tennessee, including East Tennessee Technology Park (ETTP), Oak Ridge National Lab (ORNL) and Y-12 National Security Complex (Y-12).

High –Traffic-High-Speed (HTHS) - 4-lane highways and other major roads with ≥ 0.5 km within the grid and speeds of 72.4 km/hour(45 miles/hour) or more

High-Traffic-Low-Speed (HTLS) - roads inside of the Y-12 (the National Security Complex on the ORR) and Oak Ridge National Laboratory facilities within ORR where speed limits were ≤ 32.1 km/hour (≤ 20 miles/hour) or less.

Low Traffic (LT) - secondary roads where speed limits were generally lower (48.2-72.4 km/hour, 30-45 miles/hour).

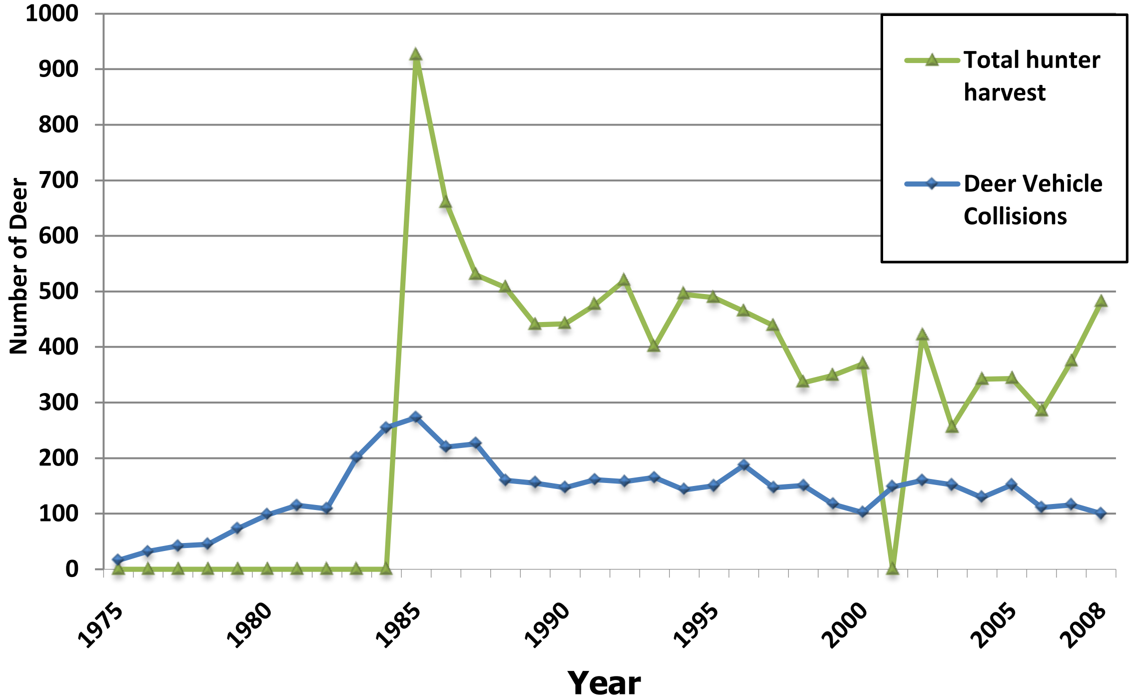


Figure 3. Number of white-tailed deer deer-vehicle collisions (DVCs) in Oak Ridge and on the Oak Ridge Reservation and hunter harvest from 1975-2008 at Oak Ridge Reservation, Tennessee. No hunt was held in 2001 due to security issues surrounding the 9/11 terrorist attacks.

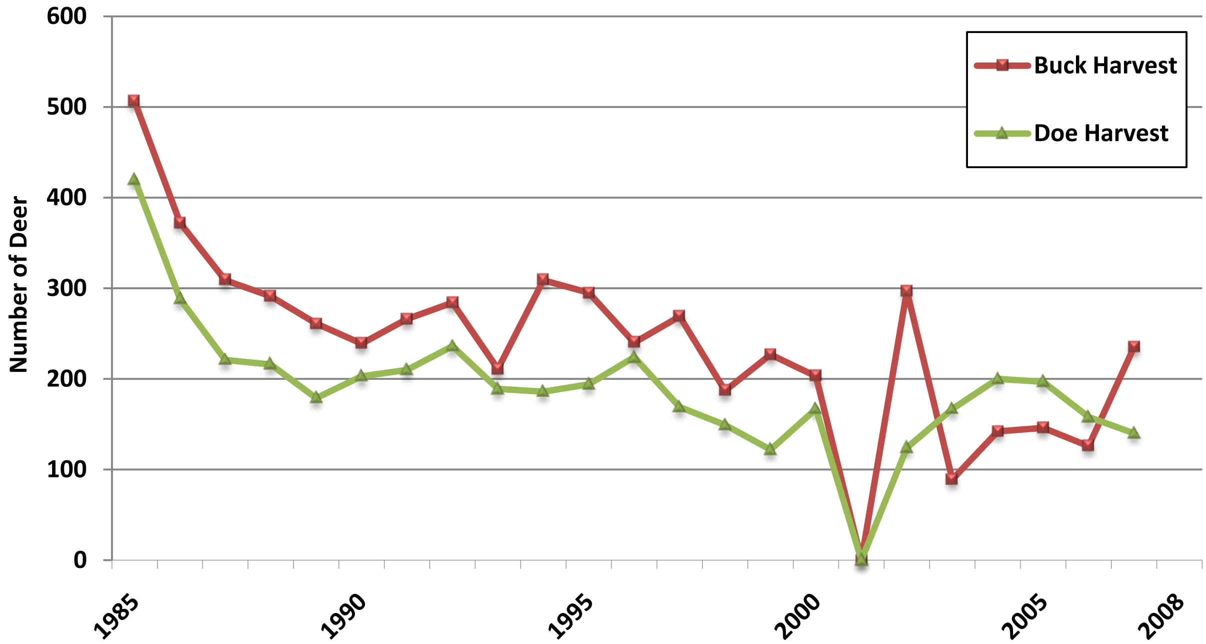


Figure 4. Number of bucks and does harvested on Oak Ridge Reservation, Tennessee from 1985 -2008. No hunt was held in 2001 due to security issues surrounding the 9/11 terrorist attacks.

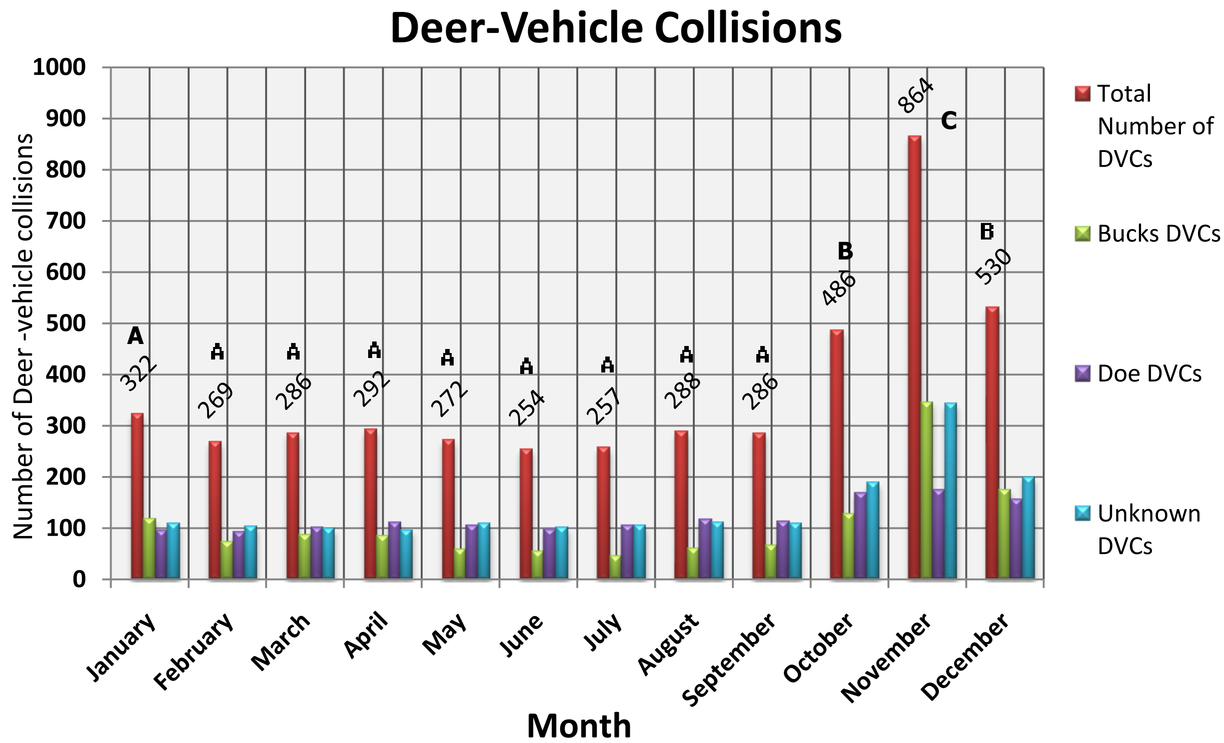


Figure 5. Number of white-tailed deer-vehicle collisions (SVCs) by month in Oak Ridge and the Oak Ridge Reservation, Tennessee from 1975-2008. A's, B's and C are Tukey's groupings for significance.

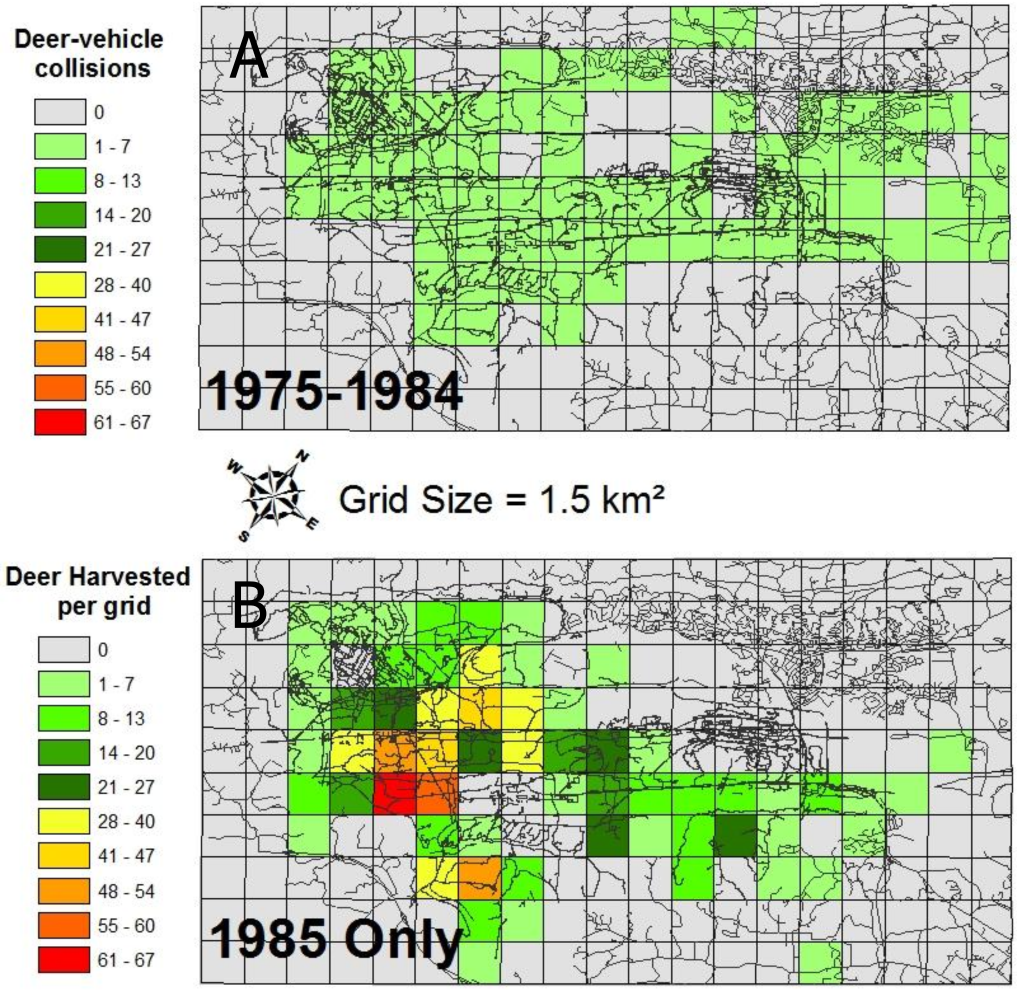


Figure 6. A) Mean annual number of deer-vehicle collisions by grid before hunting was established from 1975-1984 in Oak Ridge and the Oak Ridge Reservation, Tennessee. B) Number of deer harvested during the first deer hunt in 1985 at the Oak Ridge Reservation, Tennessee.

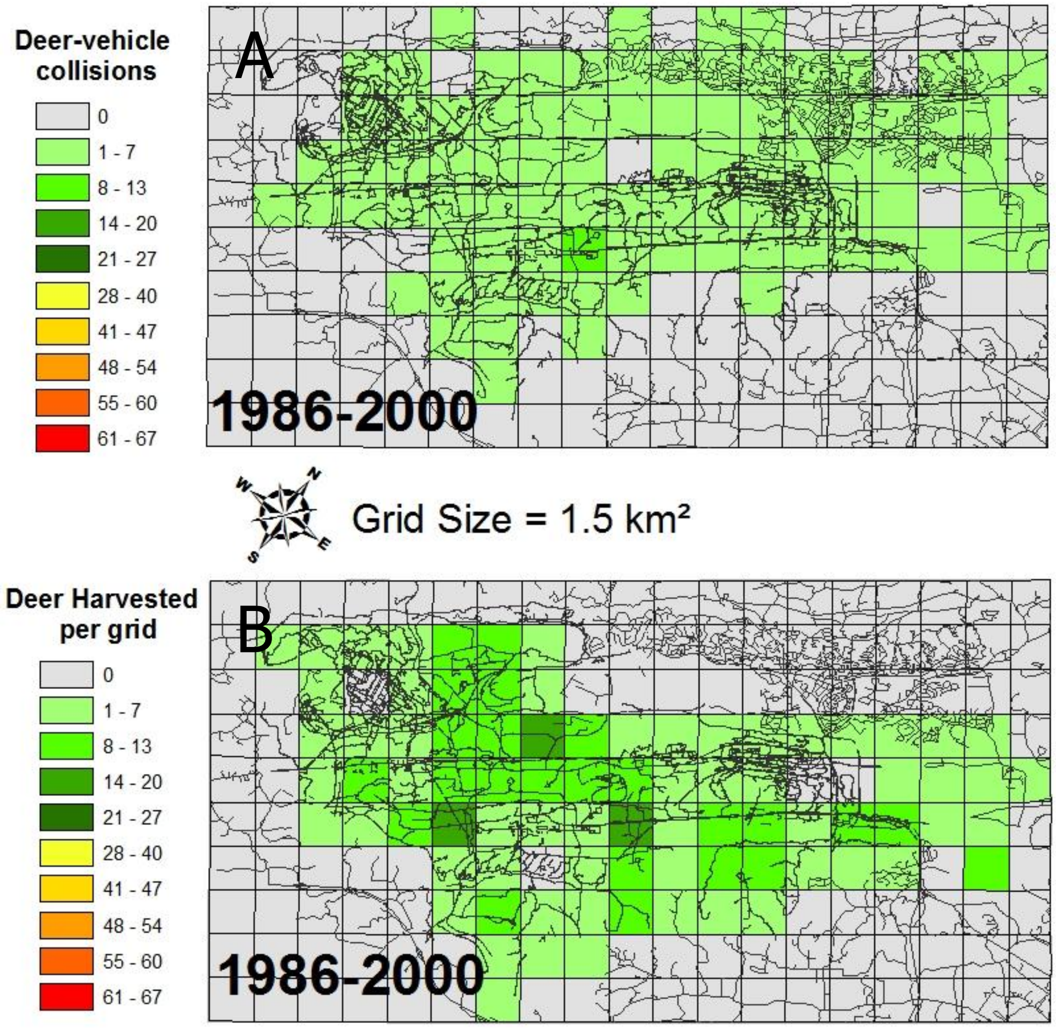


Figure 7. Hunter harvest occurred without strict security measures from 1986-2000. No hunt occurred in 2001. A) Mean number of deer-vehicle collisions from 1986-2000 in Oak Ridge and the Oak Ridge Reservation, Tennessee, Tennessee, B) Mean number of deer harvested from each grid from 1986-2000 on the Oak Ridge Reservation, Tennessee.

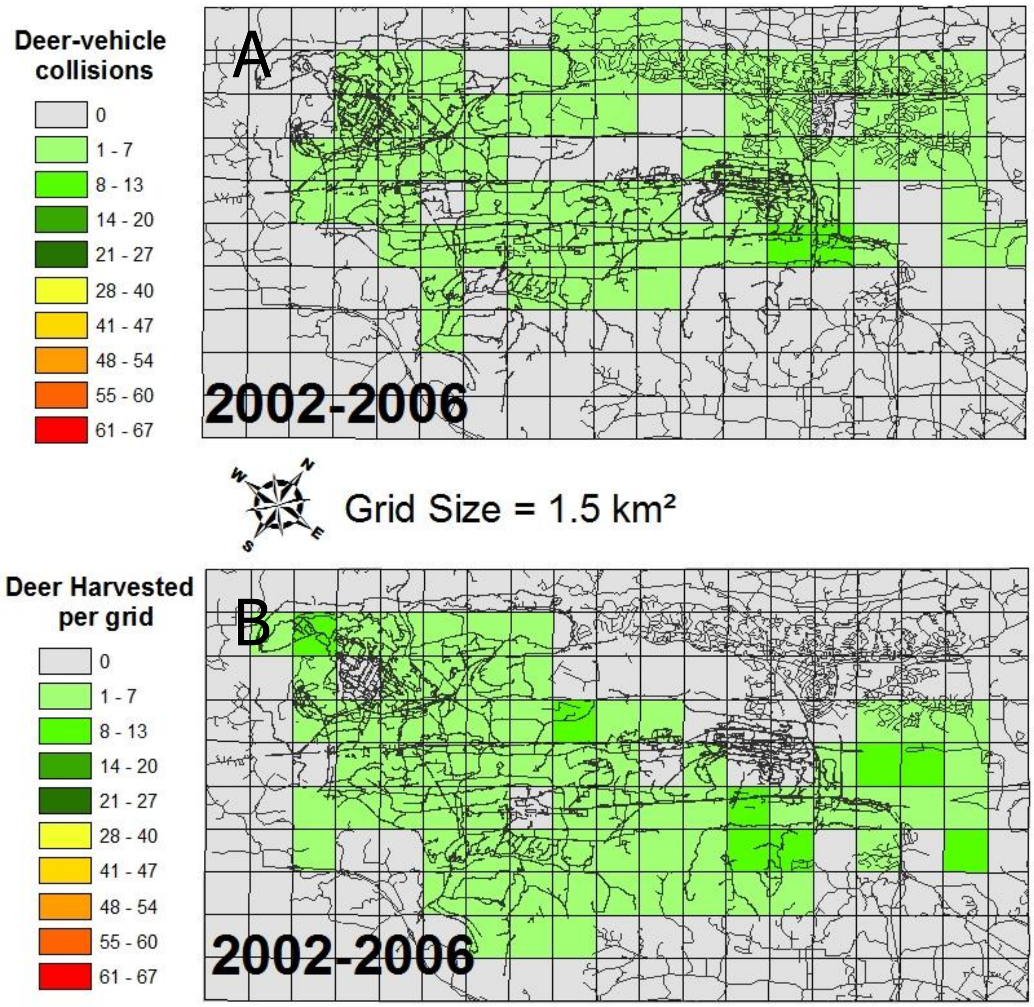


Figure 8. Strict security measures were established after September 11, 2001 and major area roads were closed to public access. A) Mean number of deer-vehicle collisions from 2002-2006 in Oak Ridge and the Oak Ridge Reservation, Tennessee, B) Mean number of harvested deer by grid from 2002-2006 on the Oak Ridge Reservation, Tennessee.

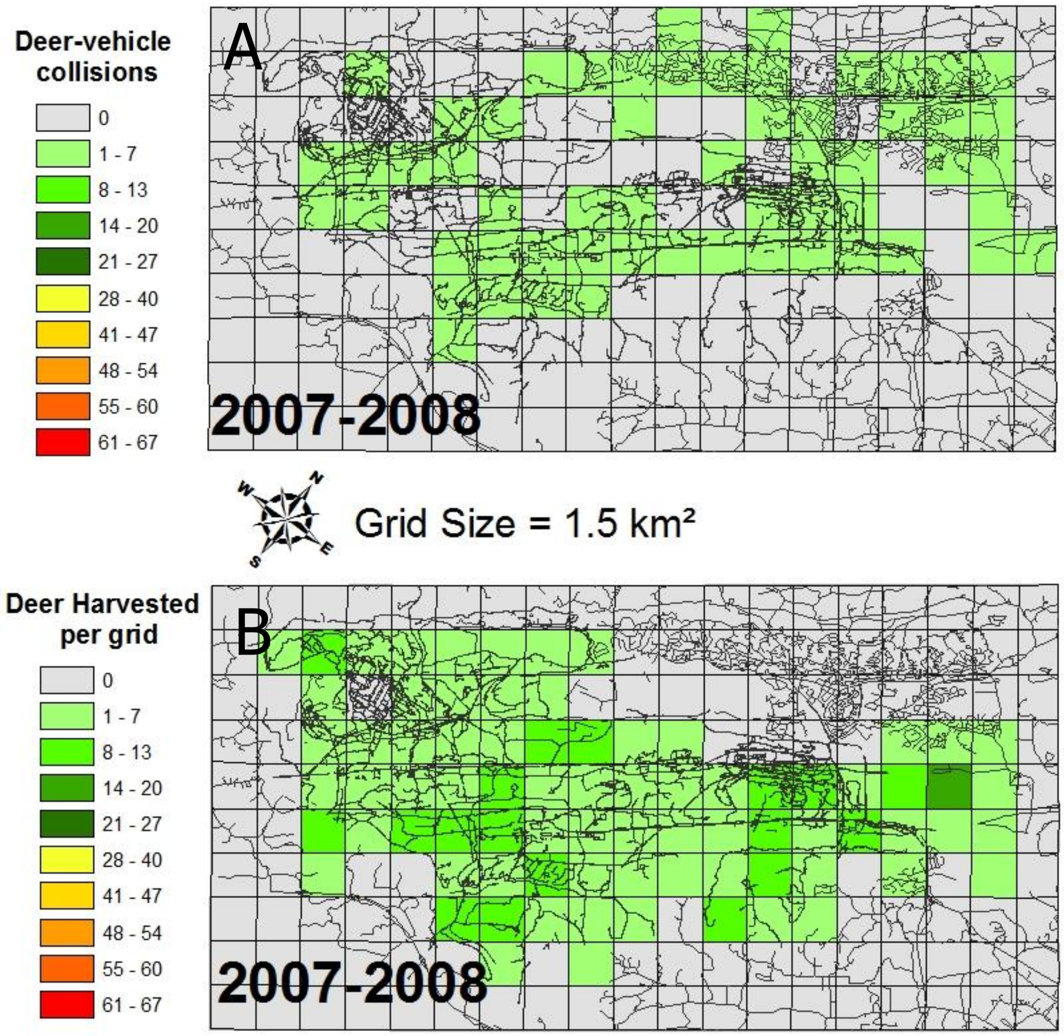
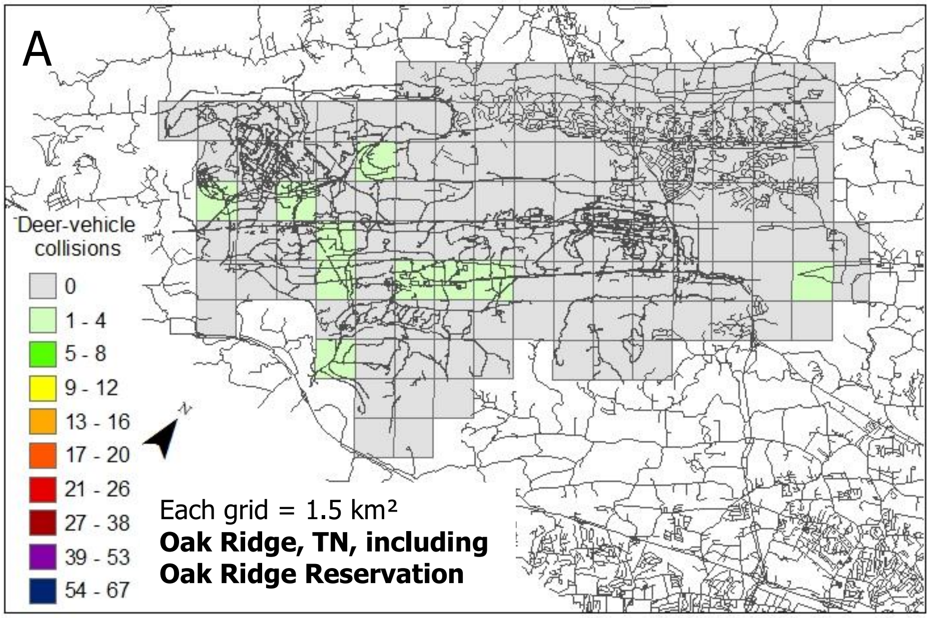


Figure 9. In 2007-2008 Antler restrictions were dropped during hunting seasons, and many more bucks were taken out of the population. A) Mean deer-vehicle collisions by grid Oak Ridge and the Oak Ridge Reservation, Tennessee, B) Mean deer harvest by grid on the Oak Ridge Reservation, Tennessee.



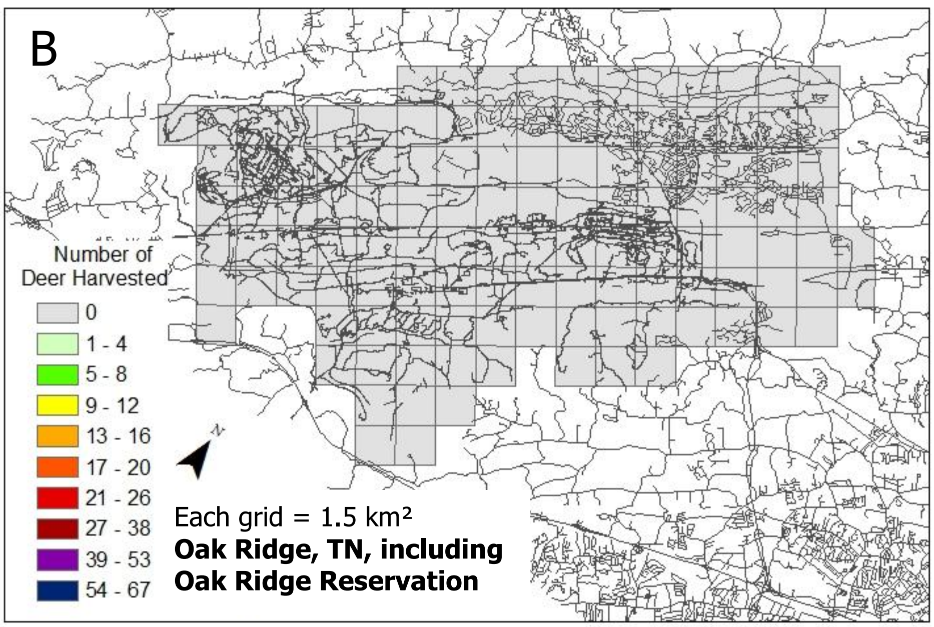


Figure 10. 1975 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

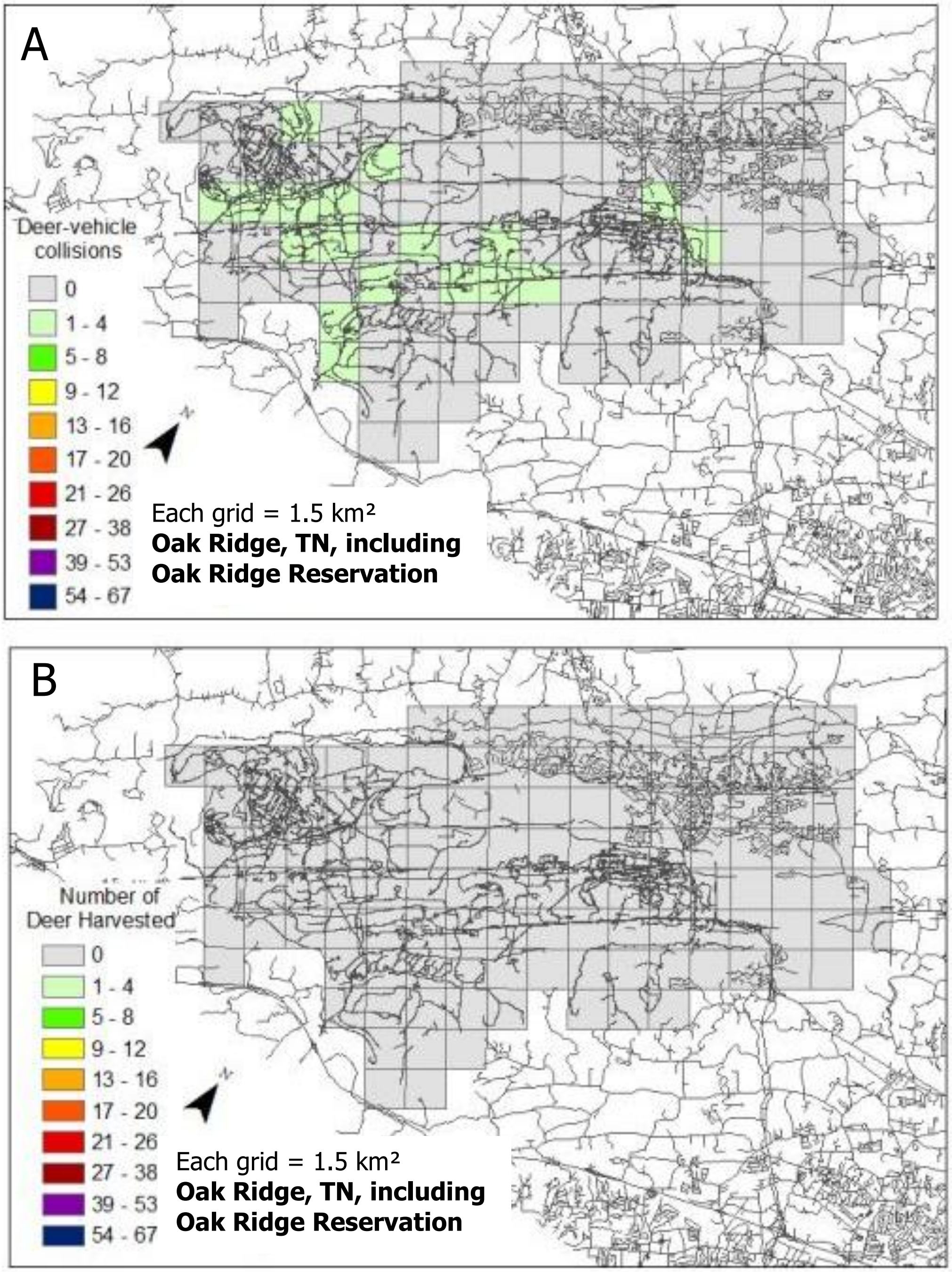


Figure 11. 1976 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

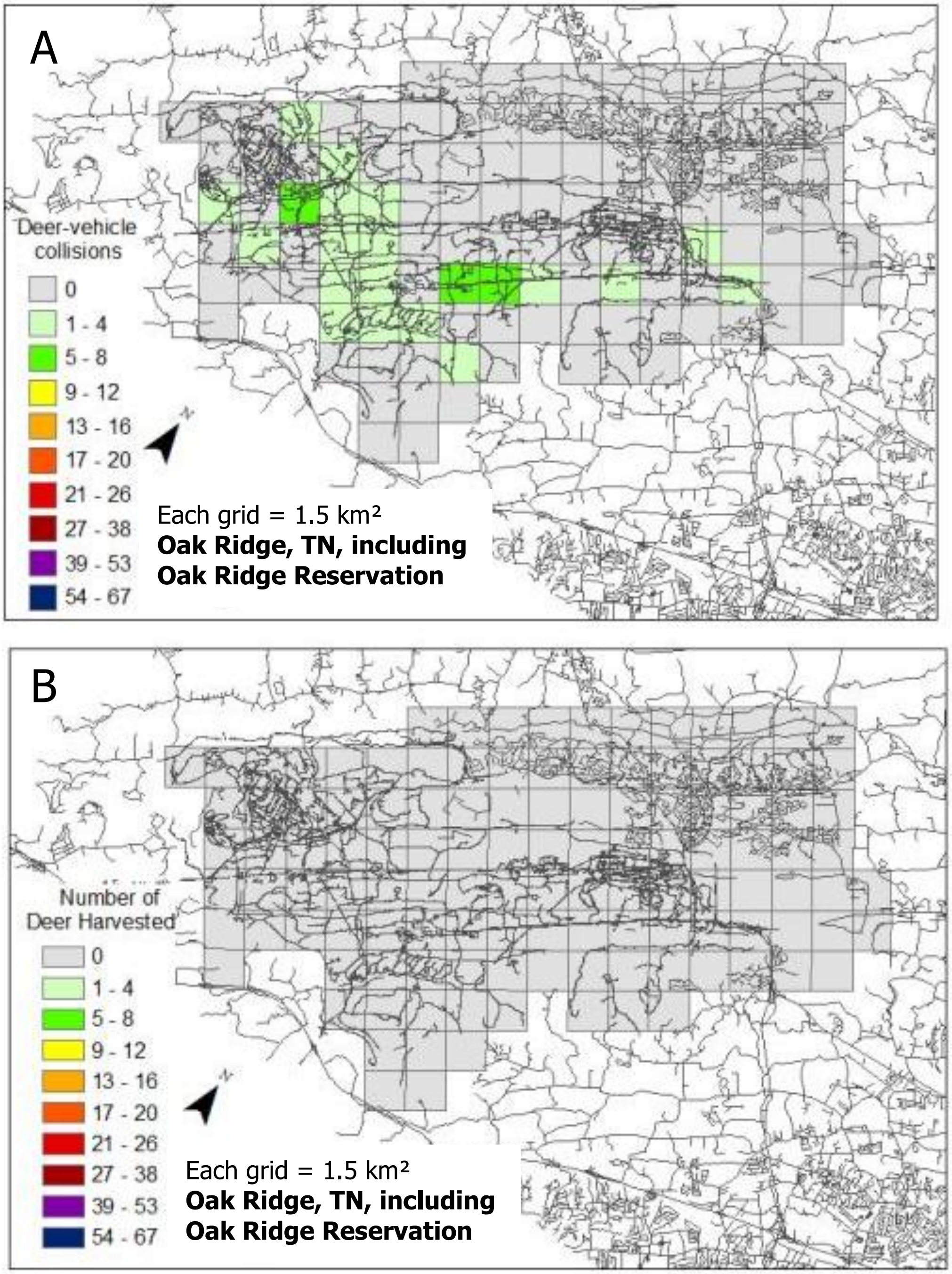


Figure 12. 1977 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

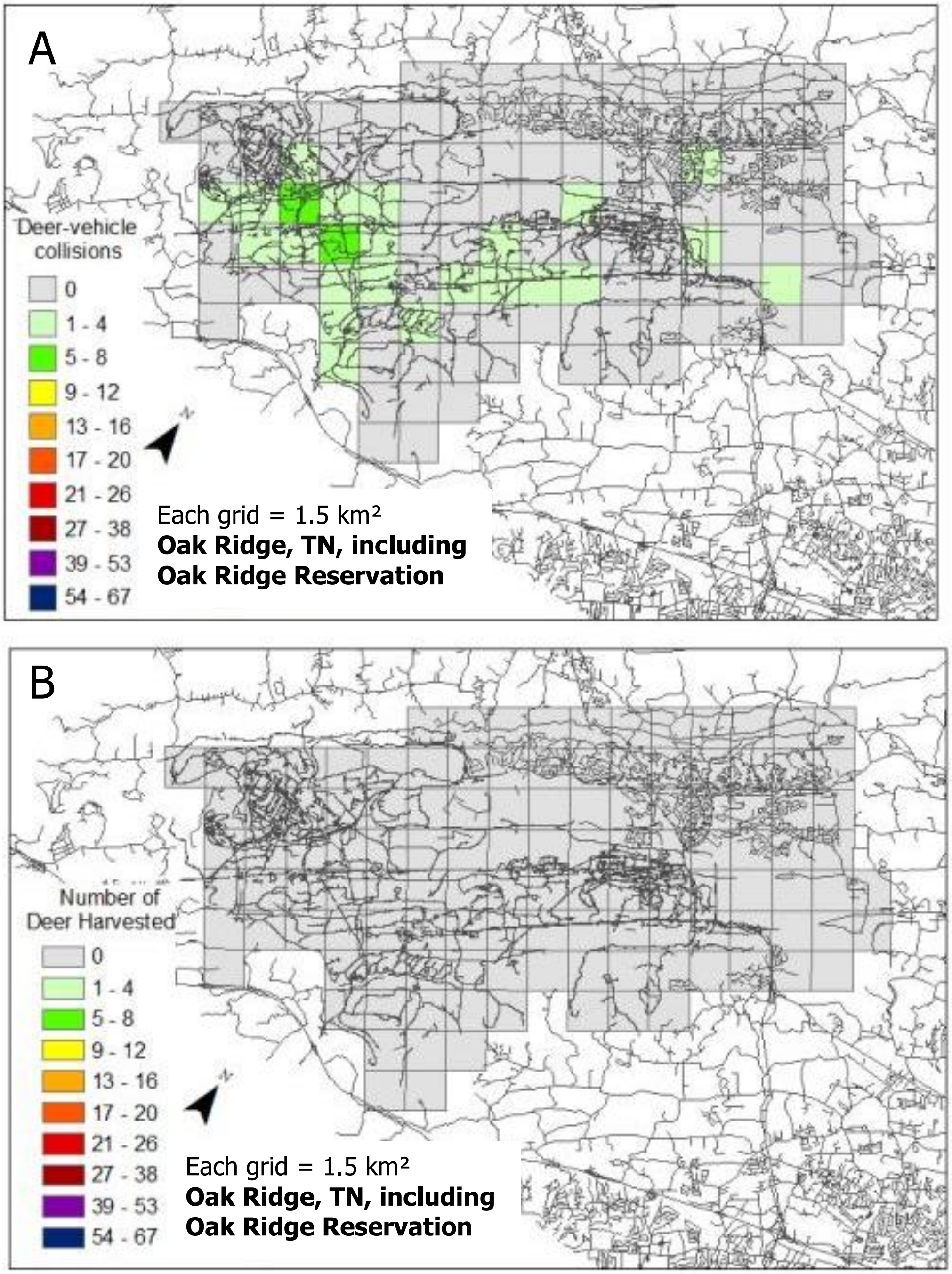


Figure 13. 1978 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

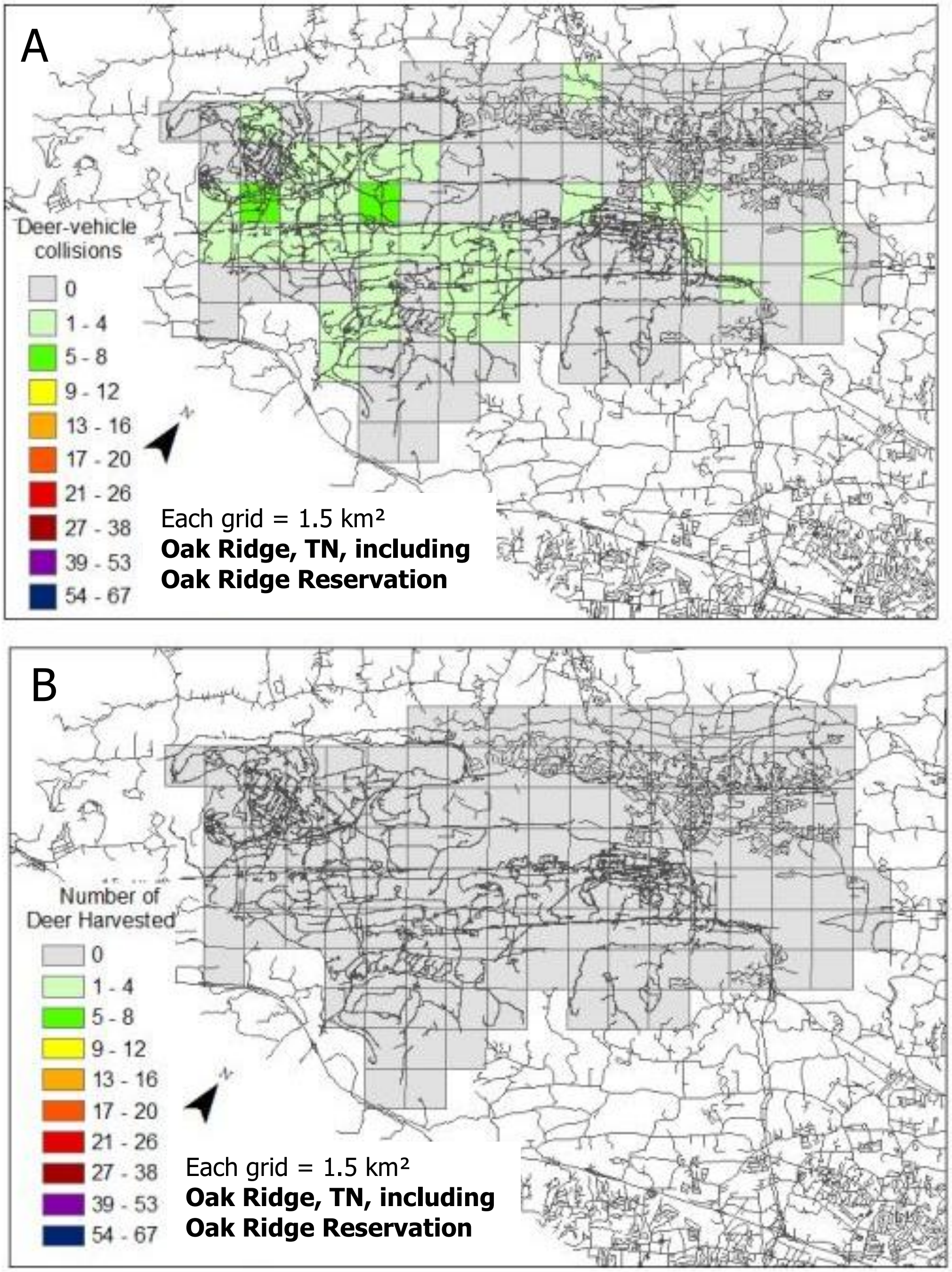
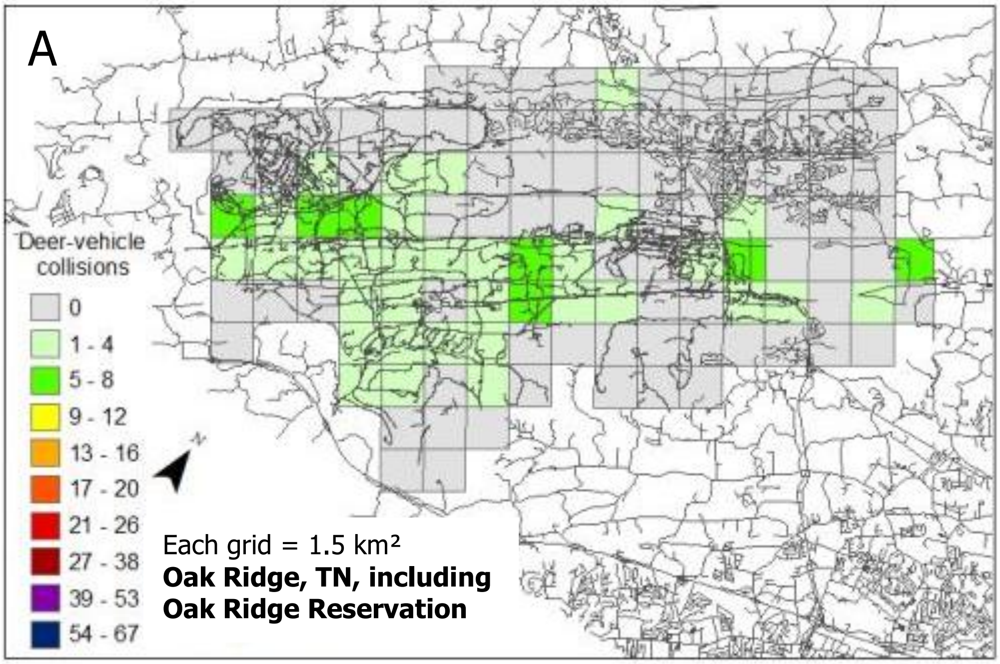


Figure 14. 1979 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.



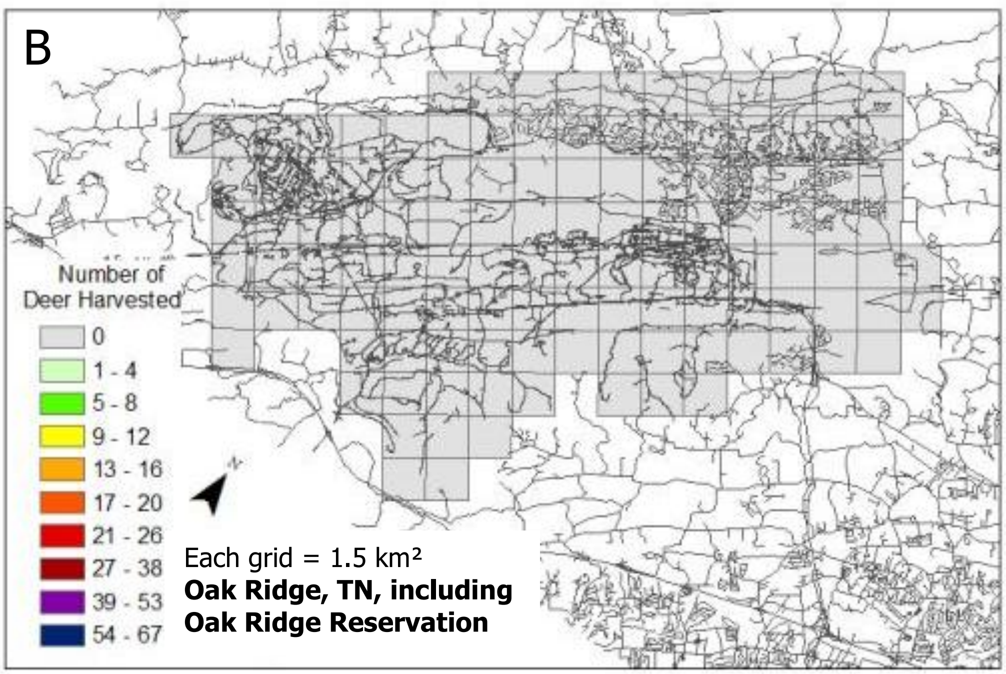


Figure 15. 1980 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

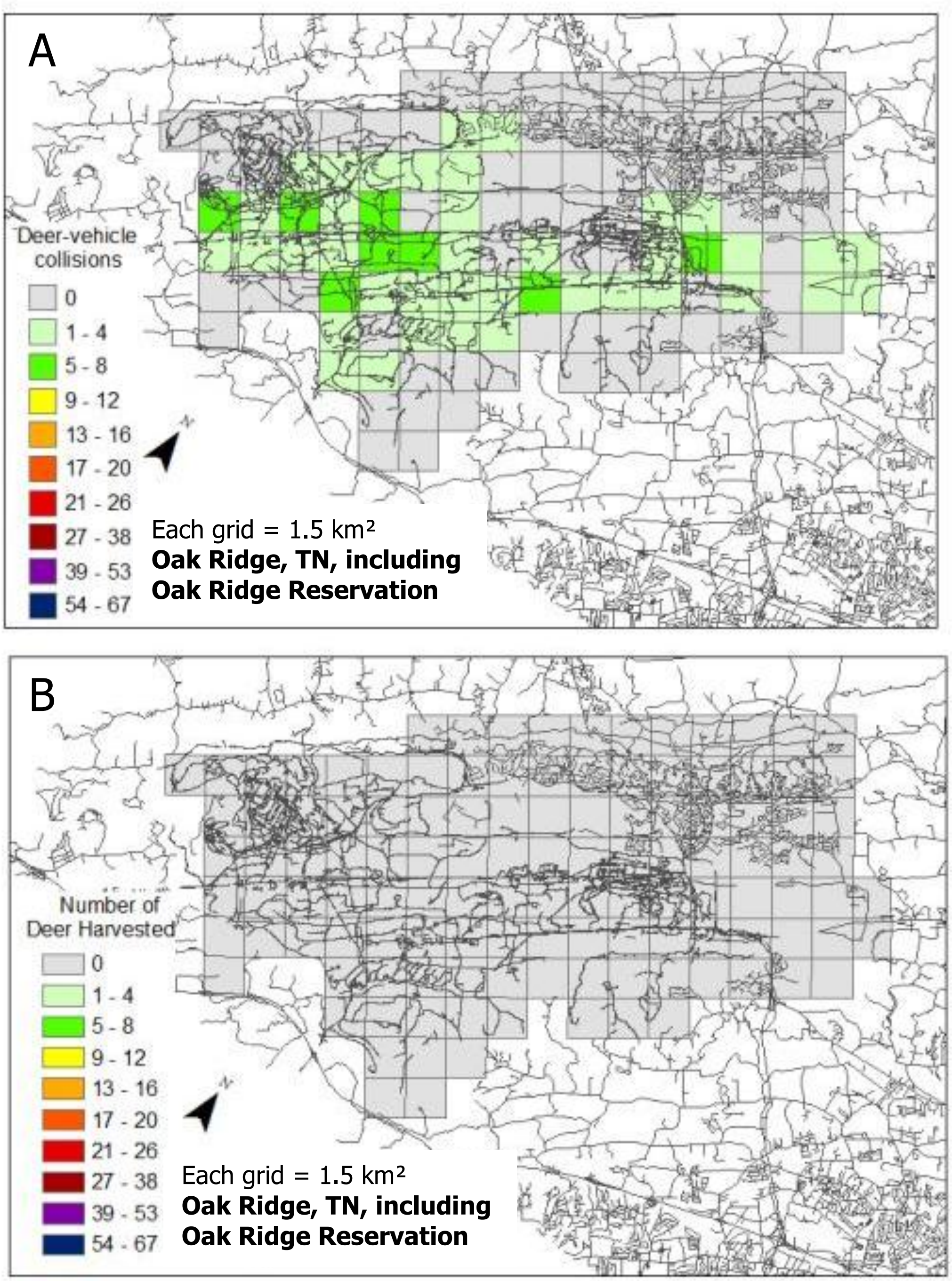


Figure 16. 1981 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

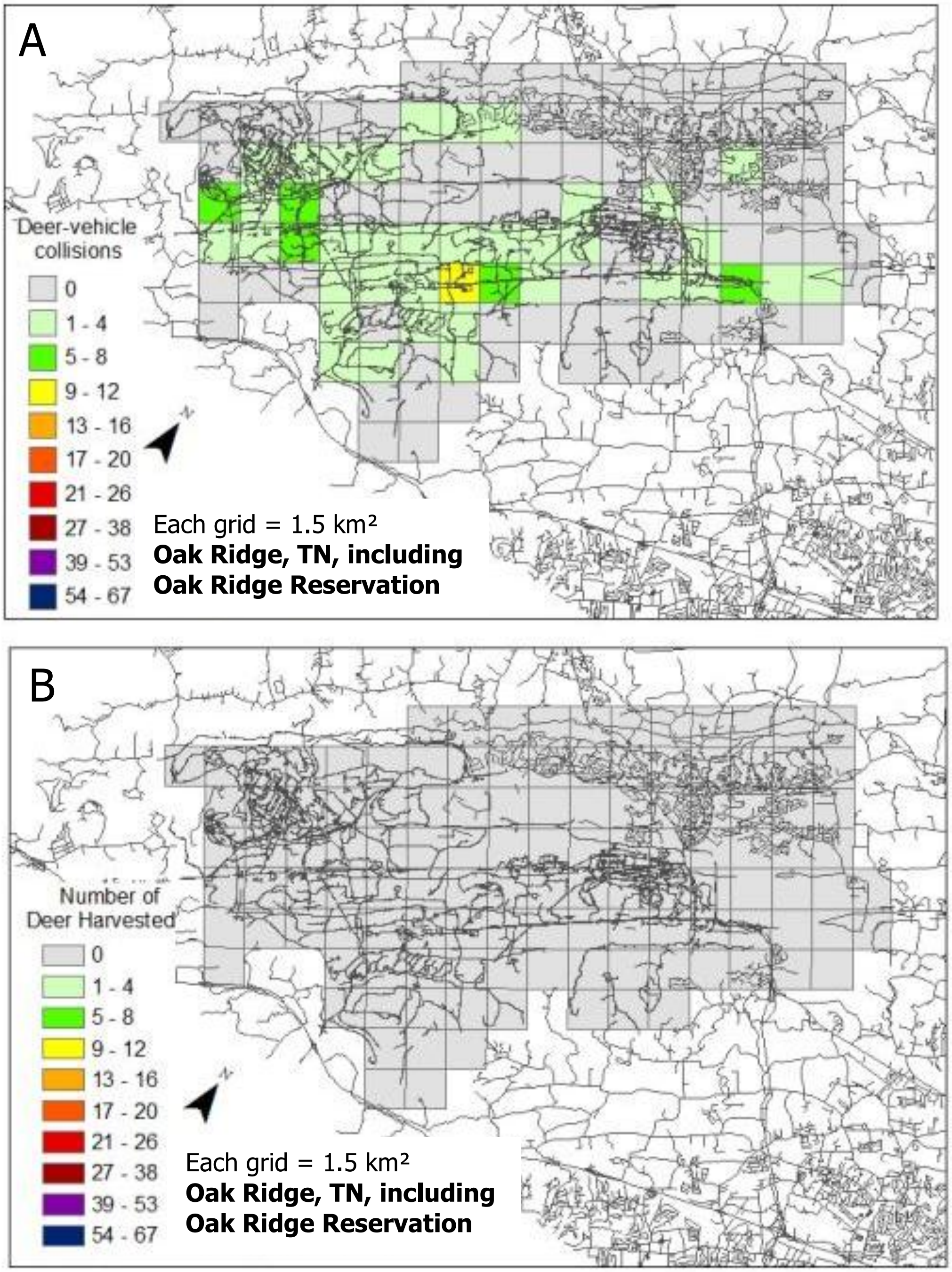


Figure 17. 1982 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

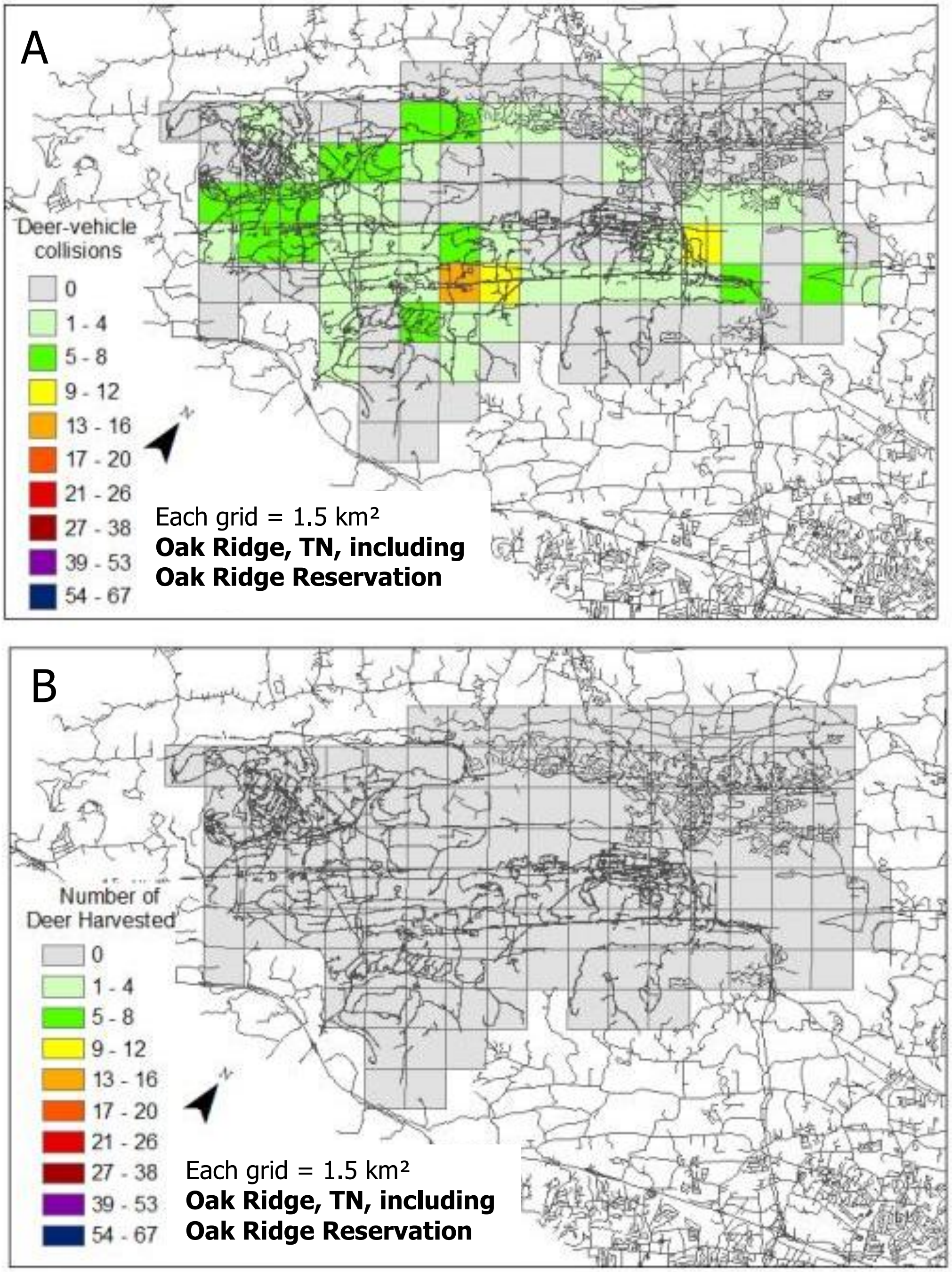


Figure 18. 1983 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

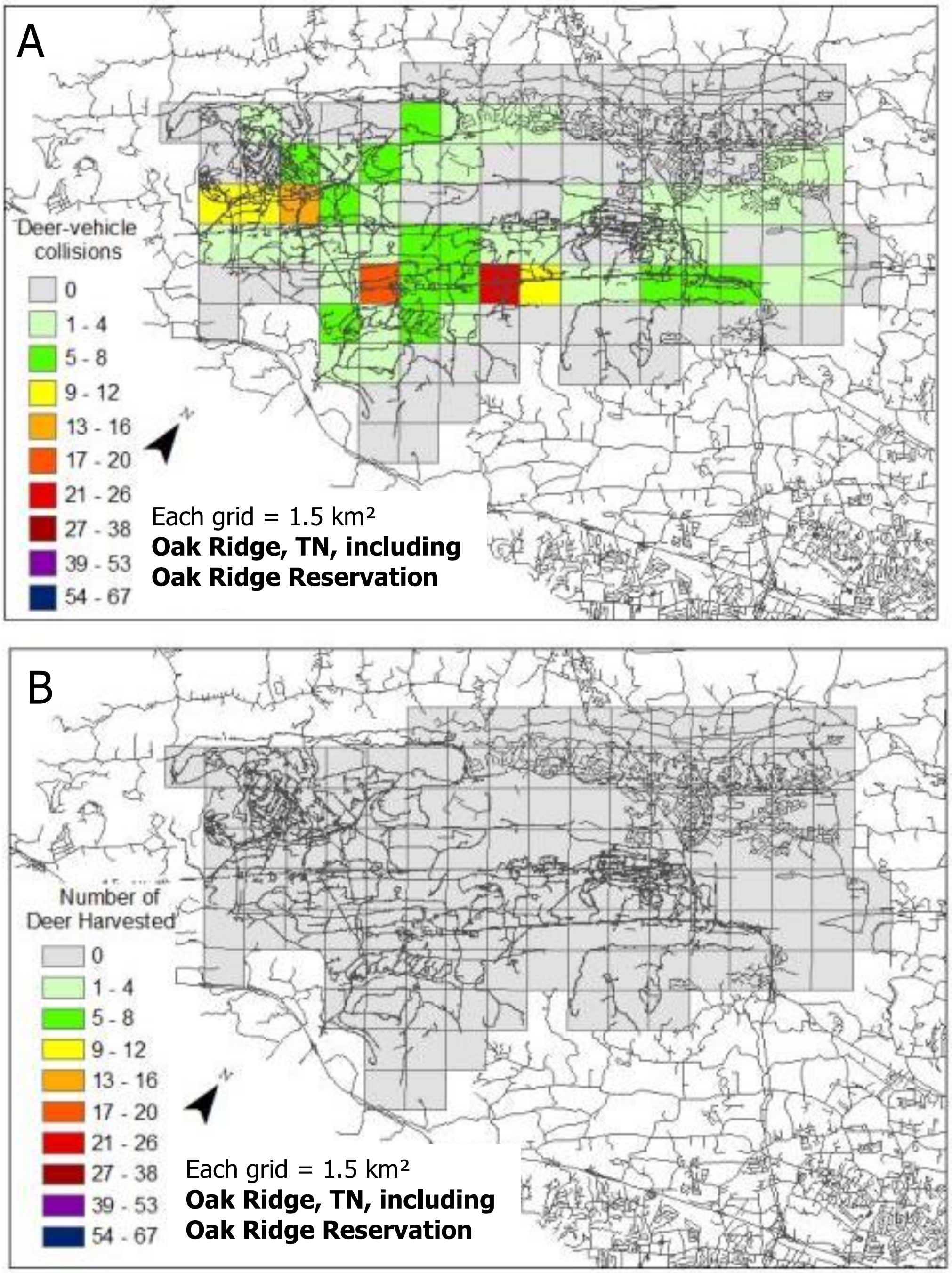


Figure 19. 1984 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

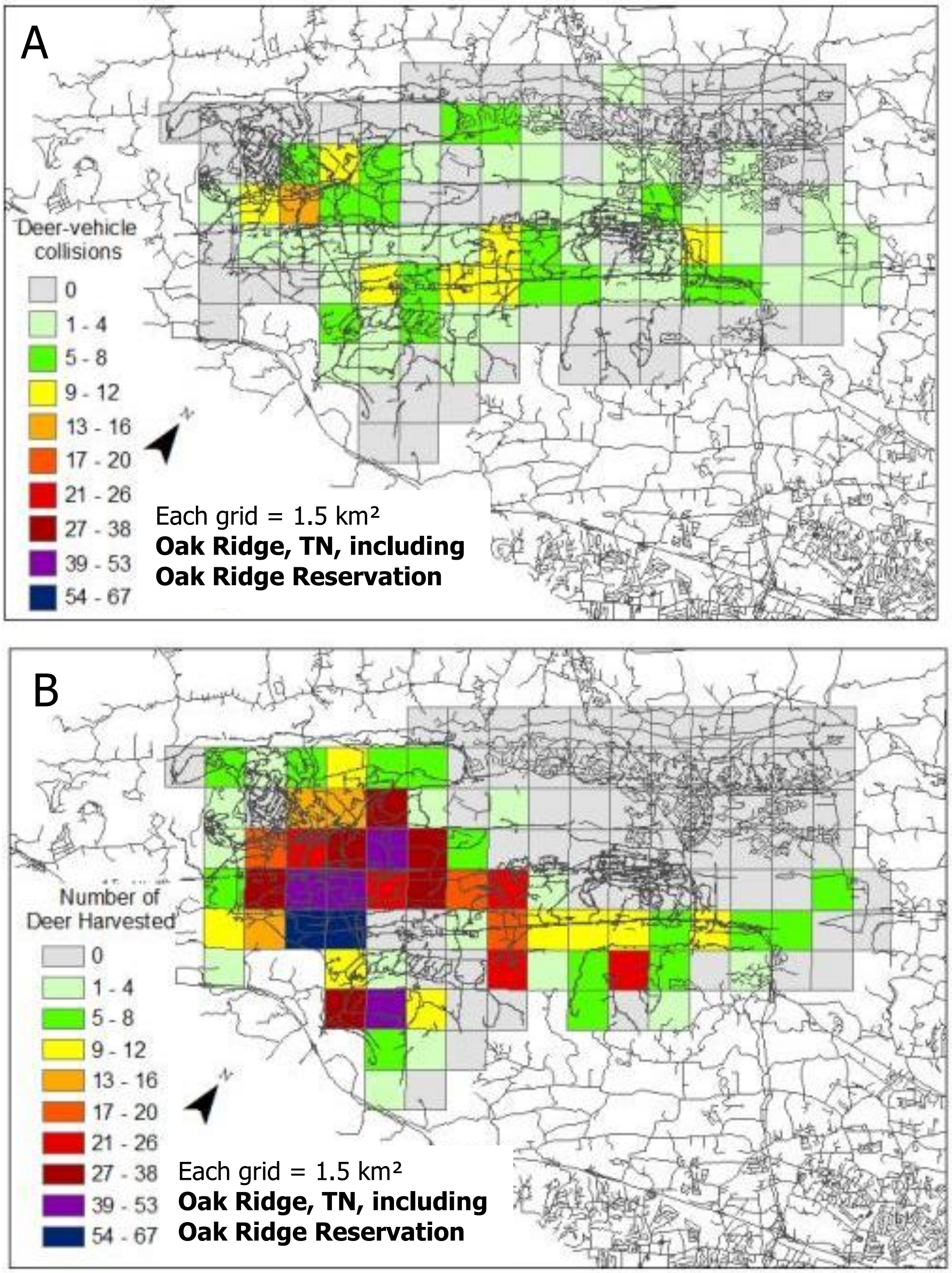


Figure 20. 1985 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

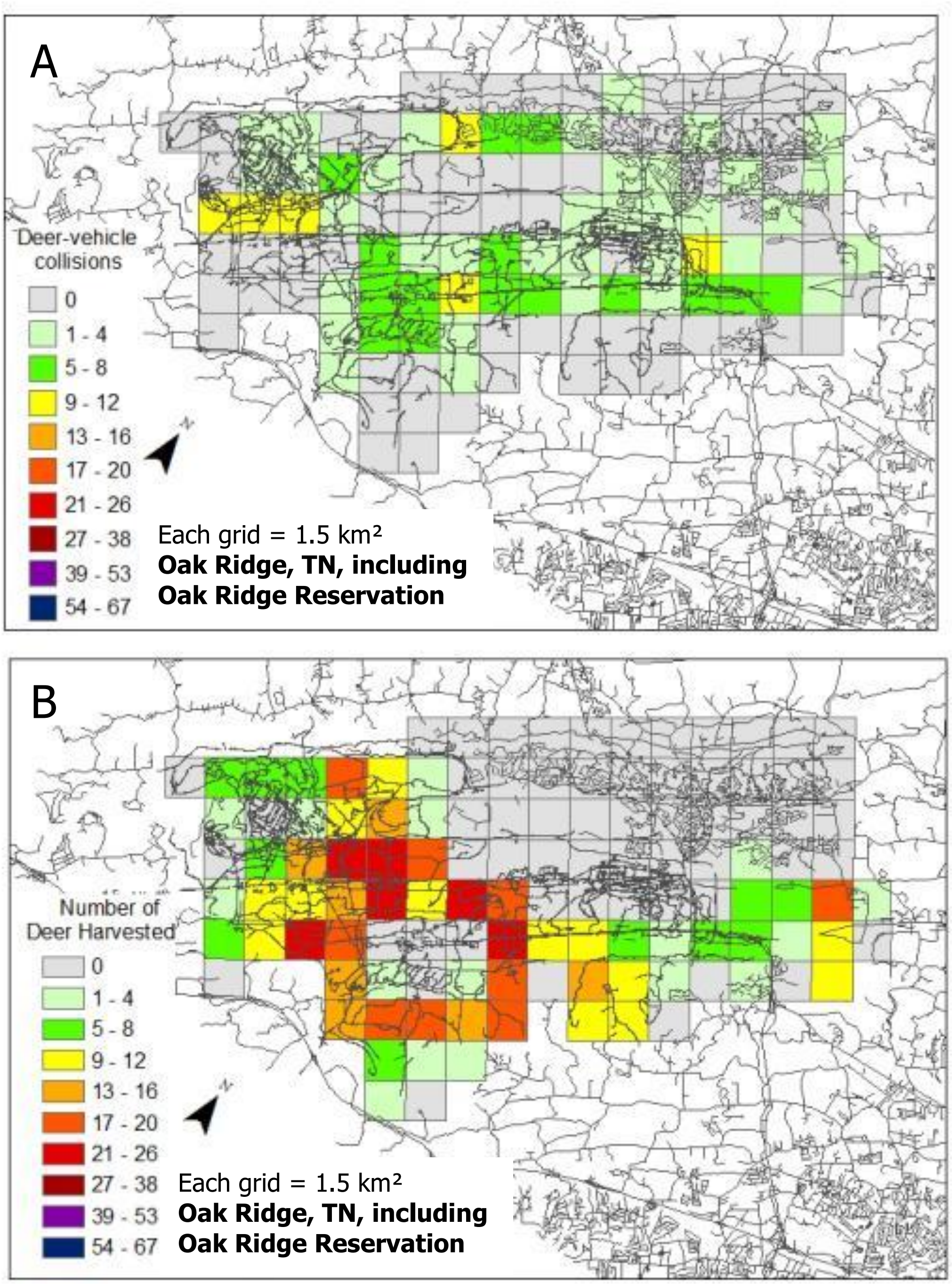


Figure 21. 1986 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

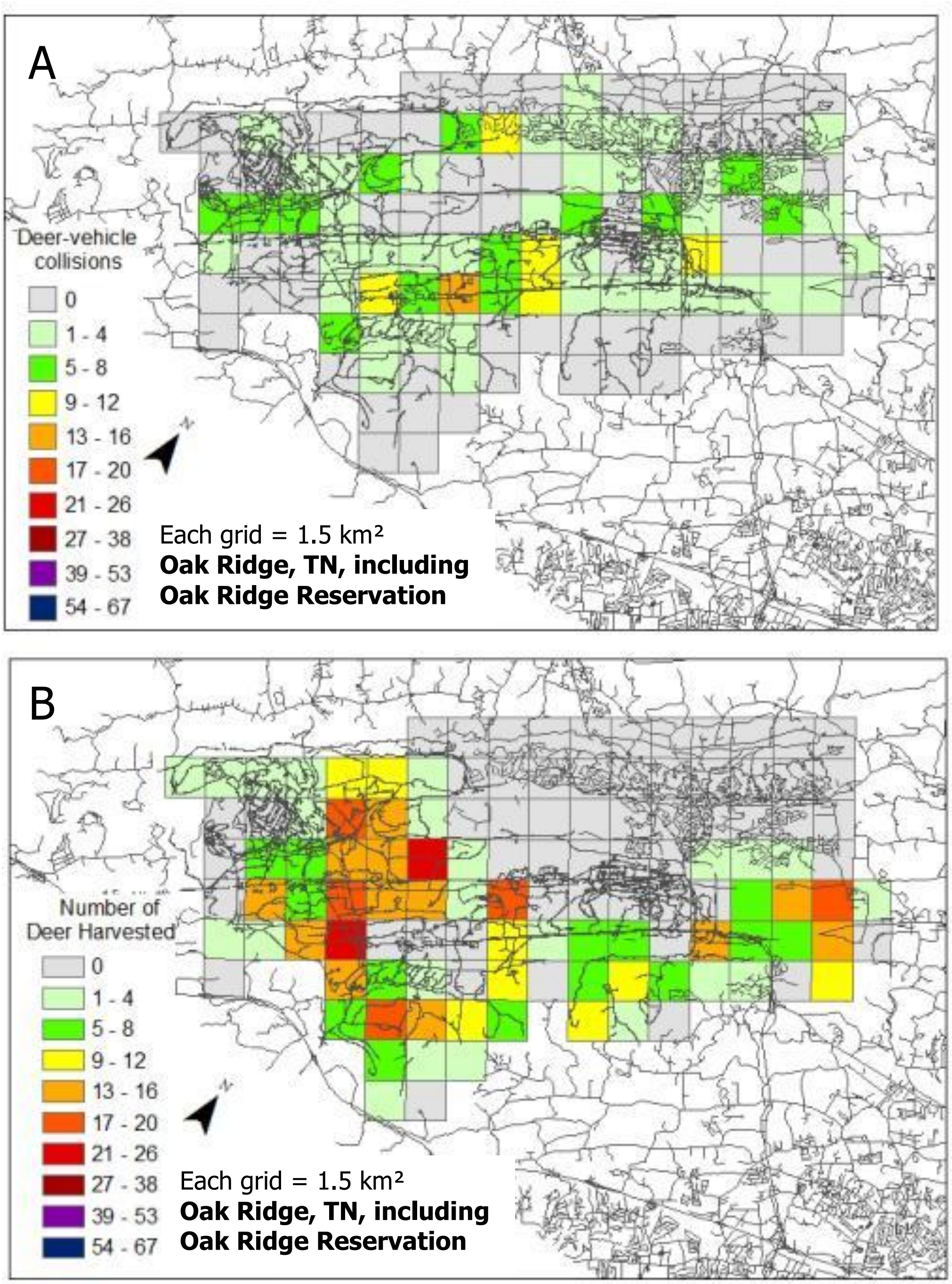


Figure 22. 1987 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

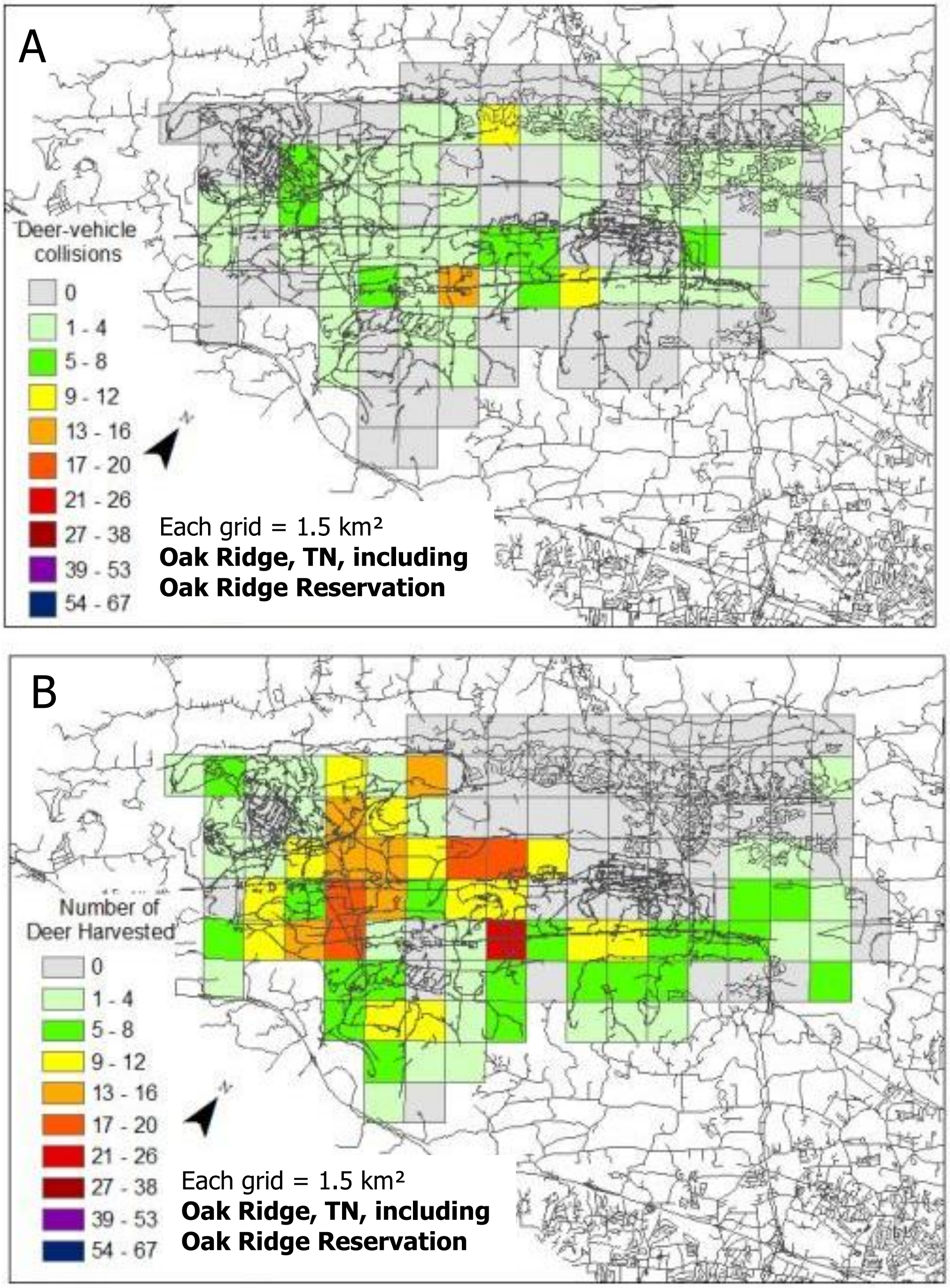


Figure 23. 1988 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

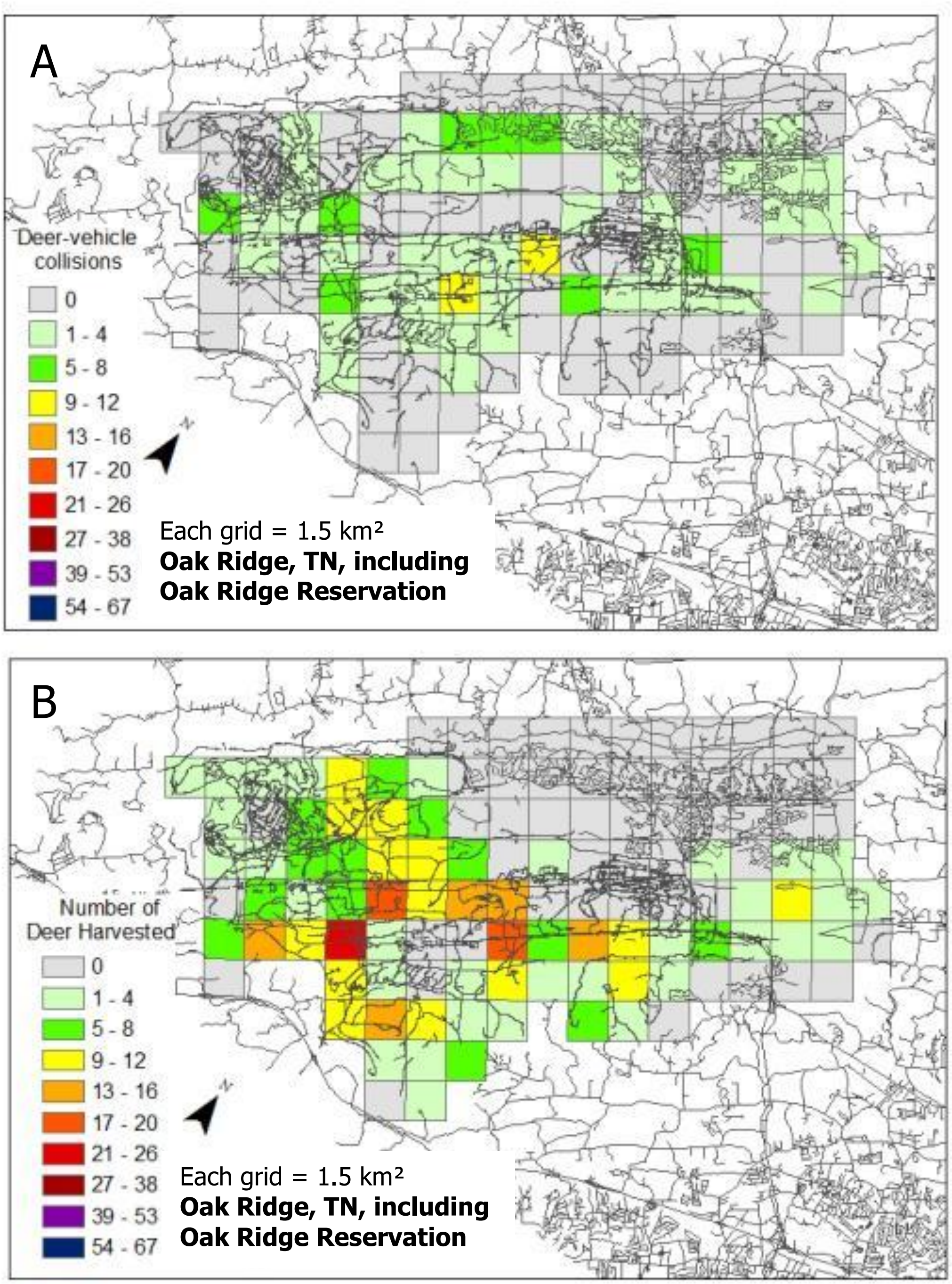
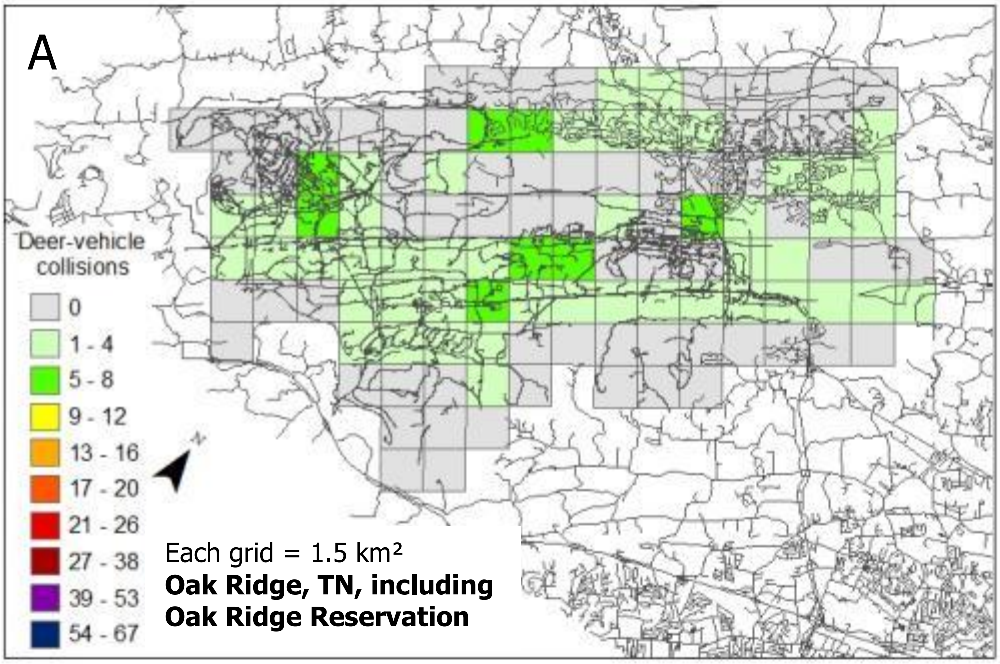


Figure 24. 1989 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.



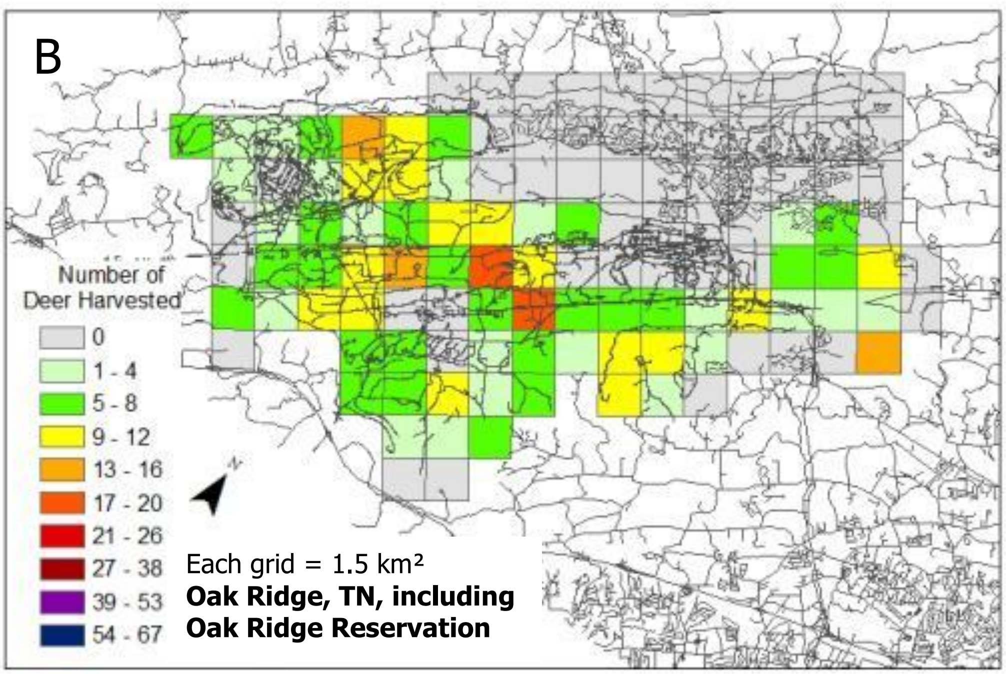


Figure 25. 1990 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

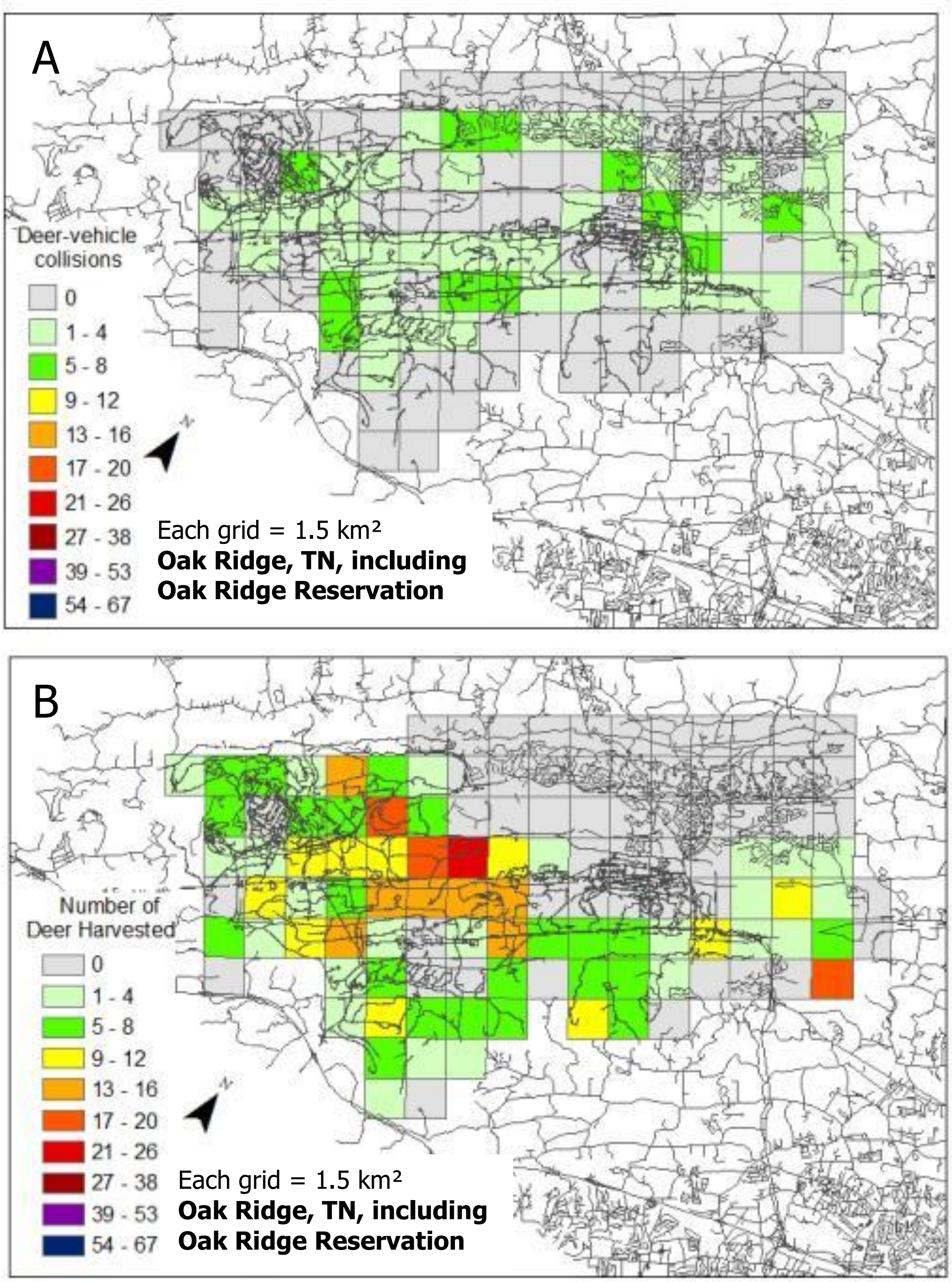


Figure 26. 1991 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

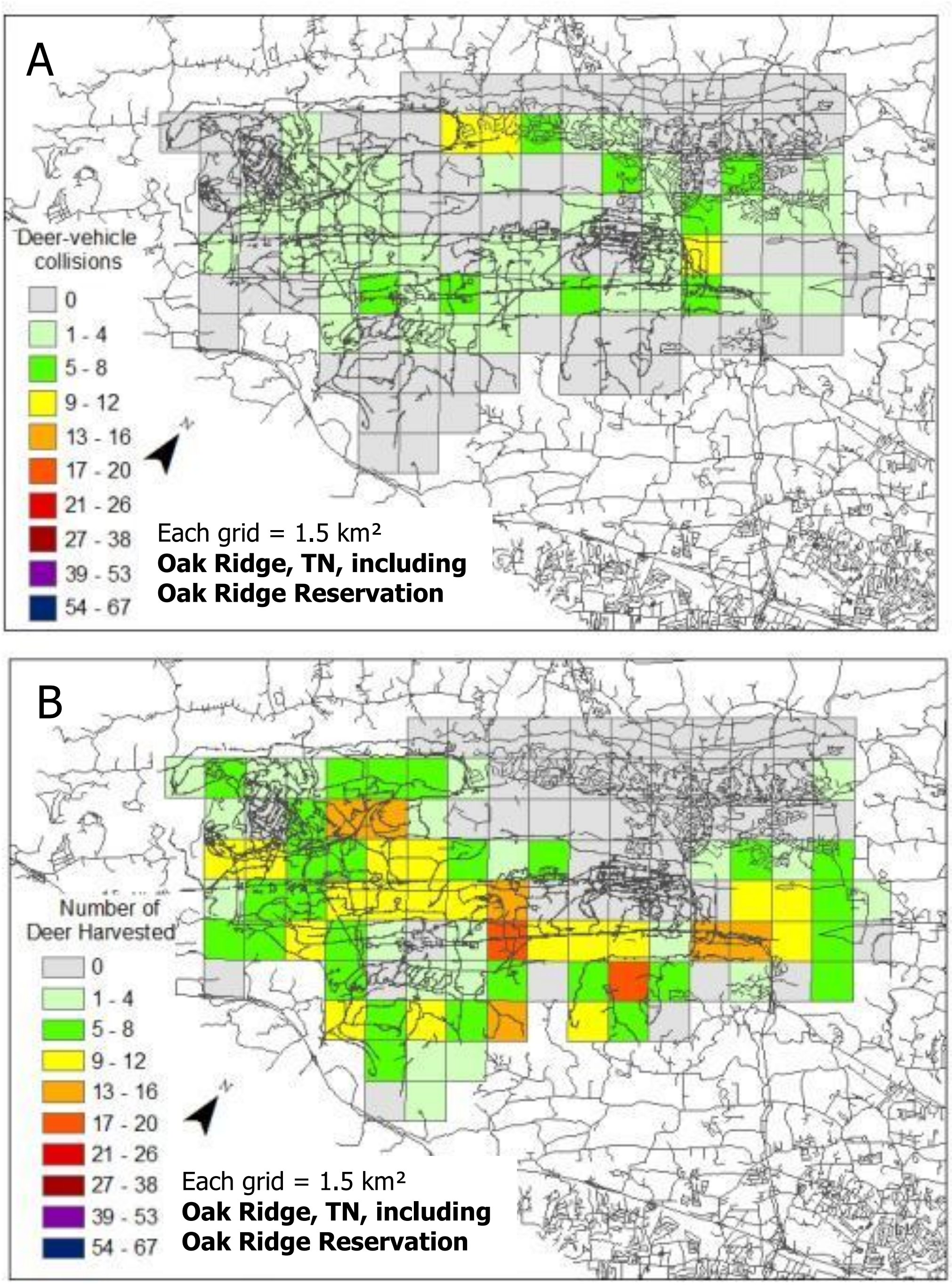
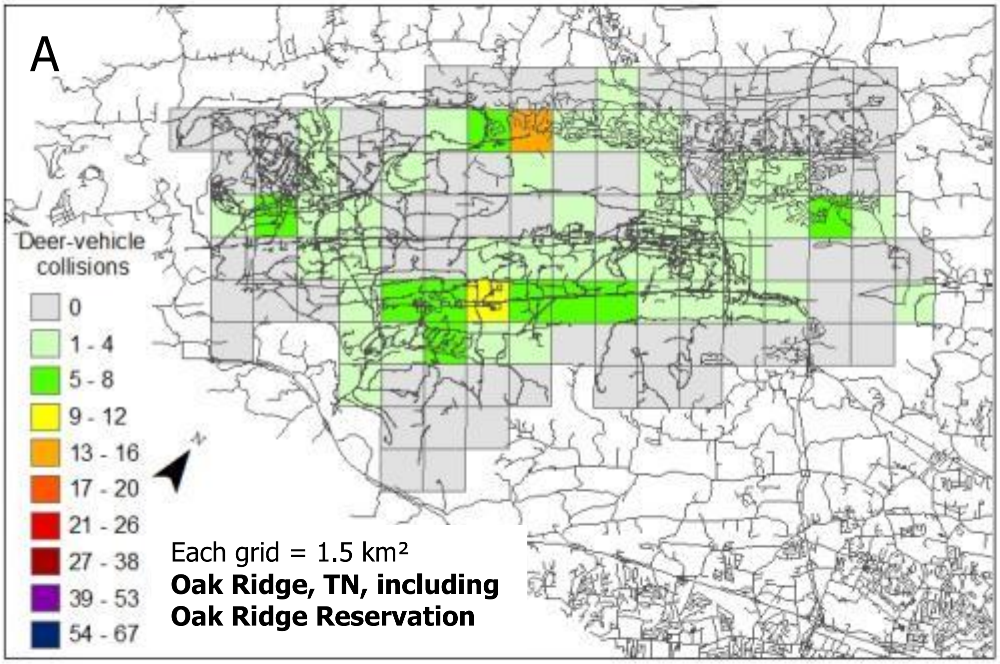


Figure 27. 1992 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.



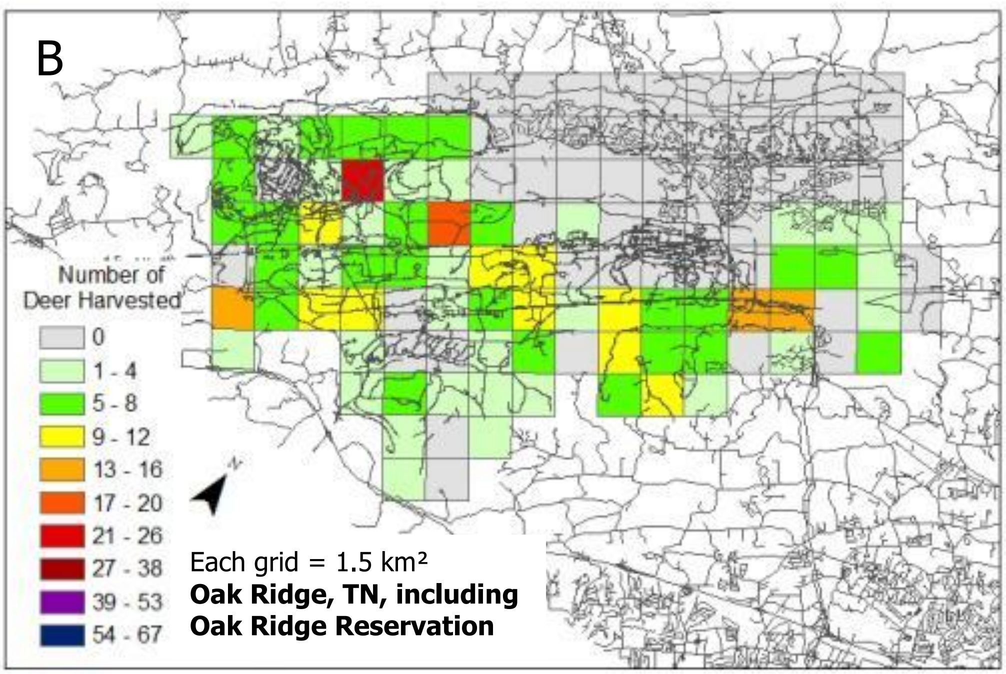


Figure 28. 1993 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

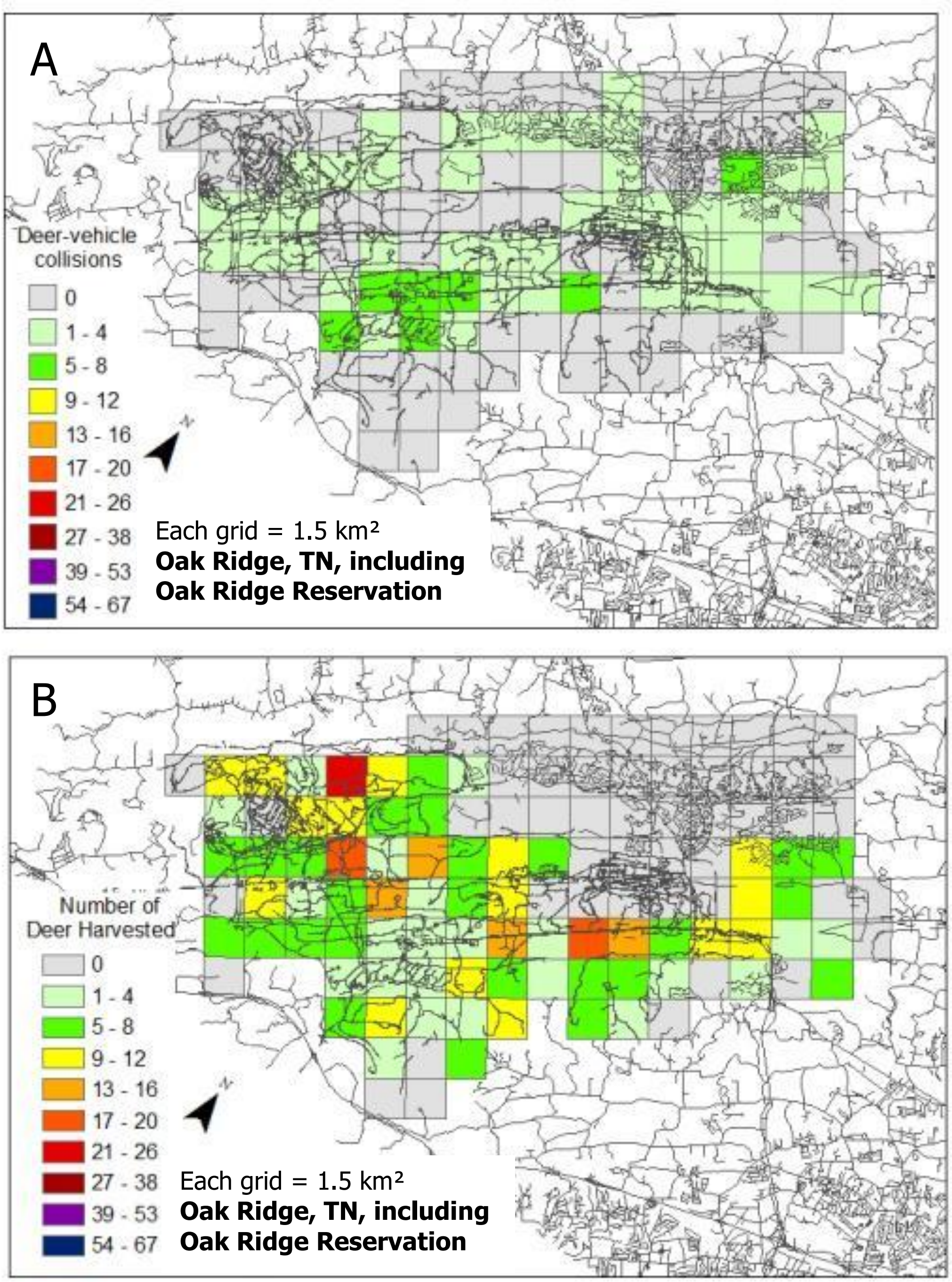
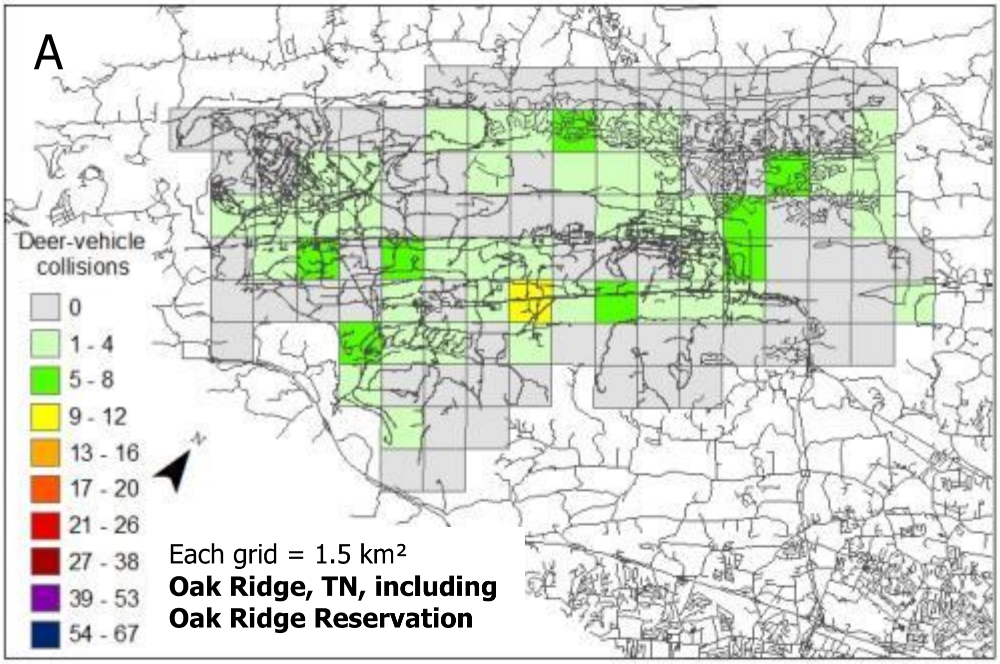


Figure 29. 1994 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.



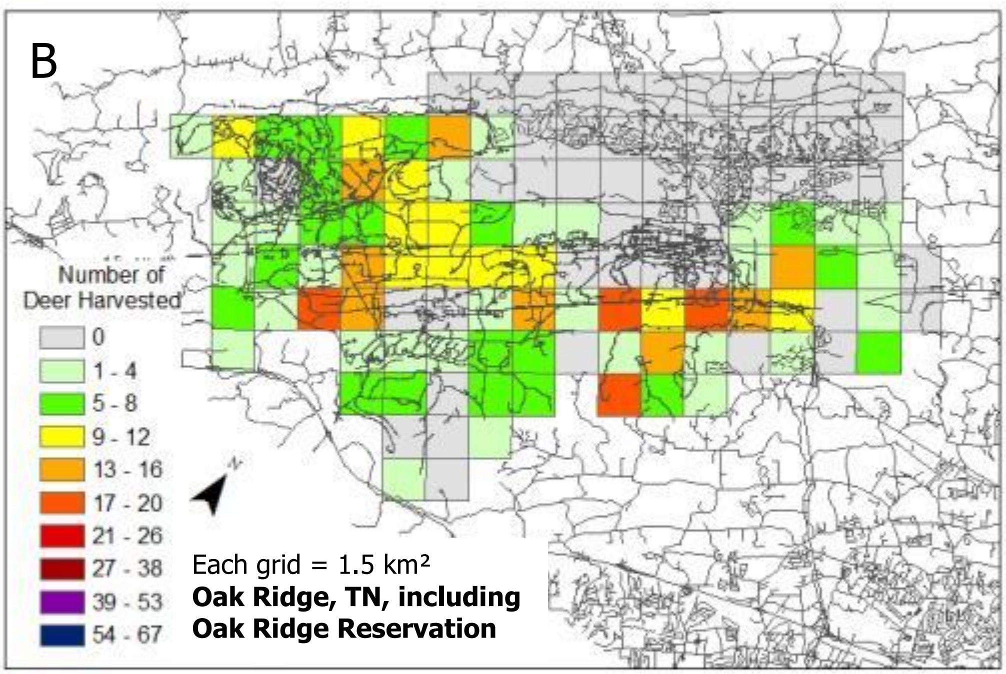


Figure 30. 1995 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

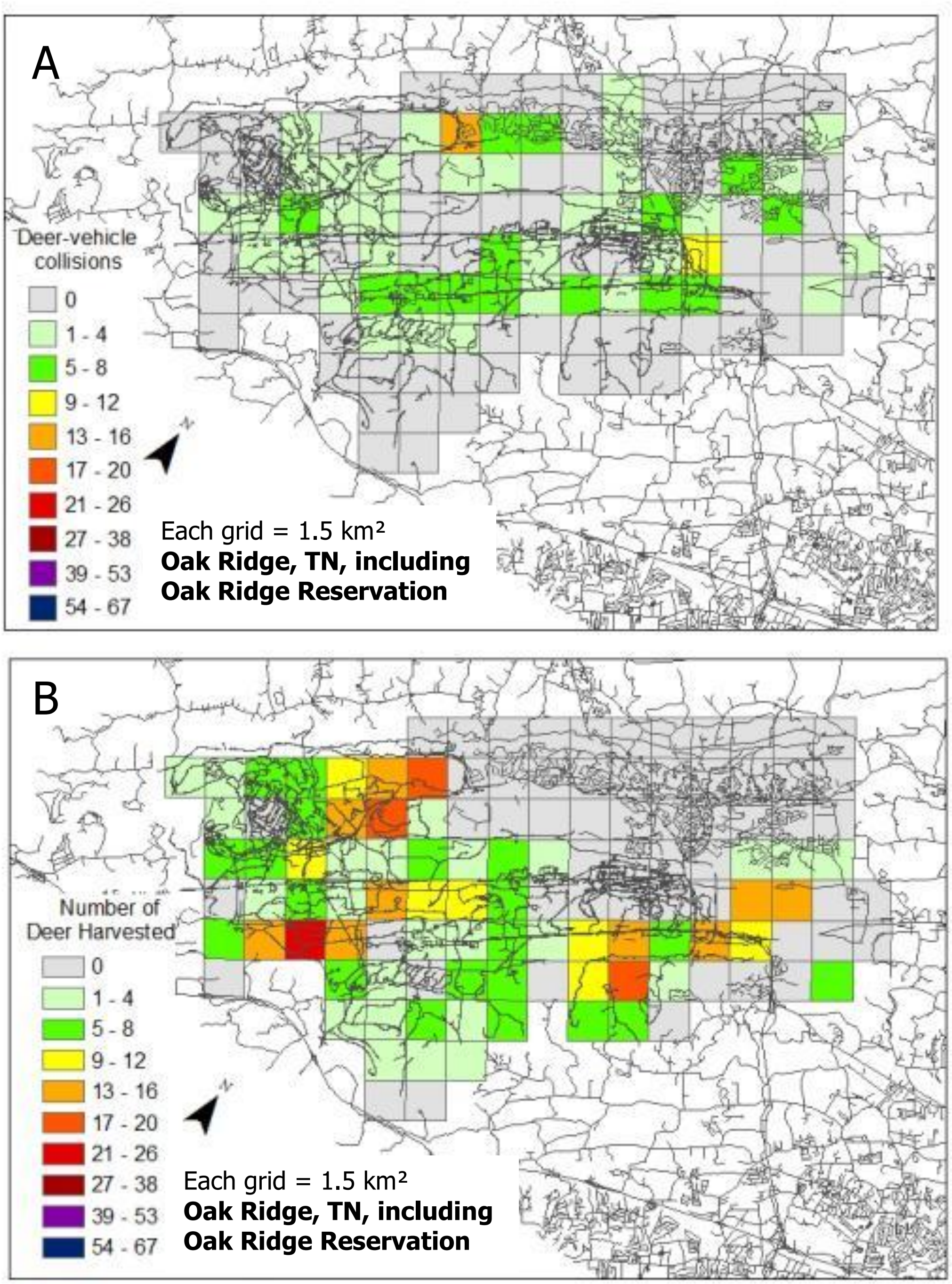


Figure 31. 1996 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

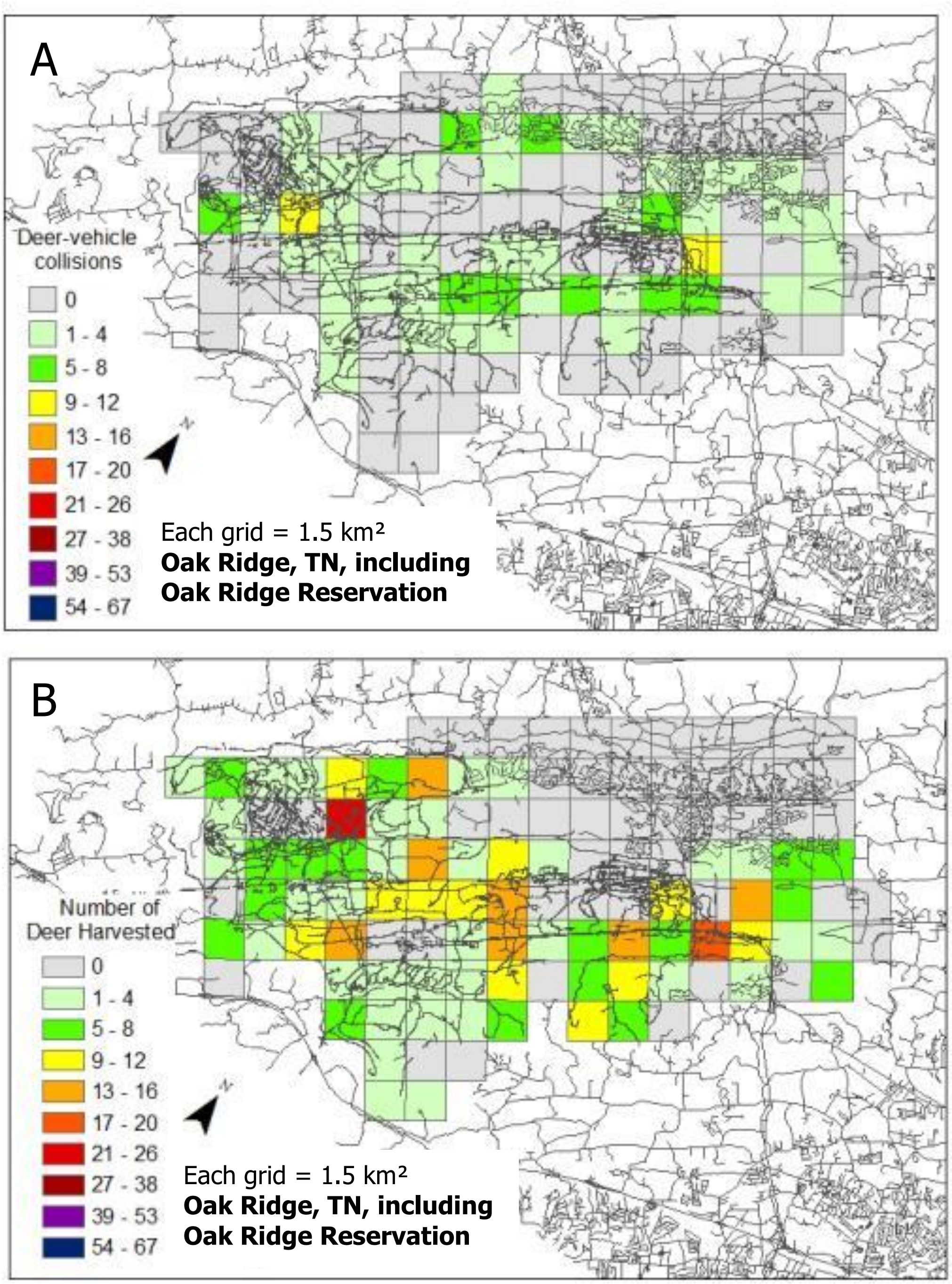


Figure 32. 1997 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

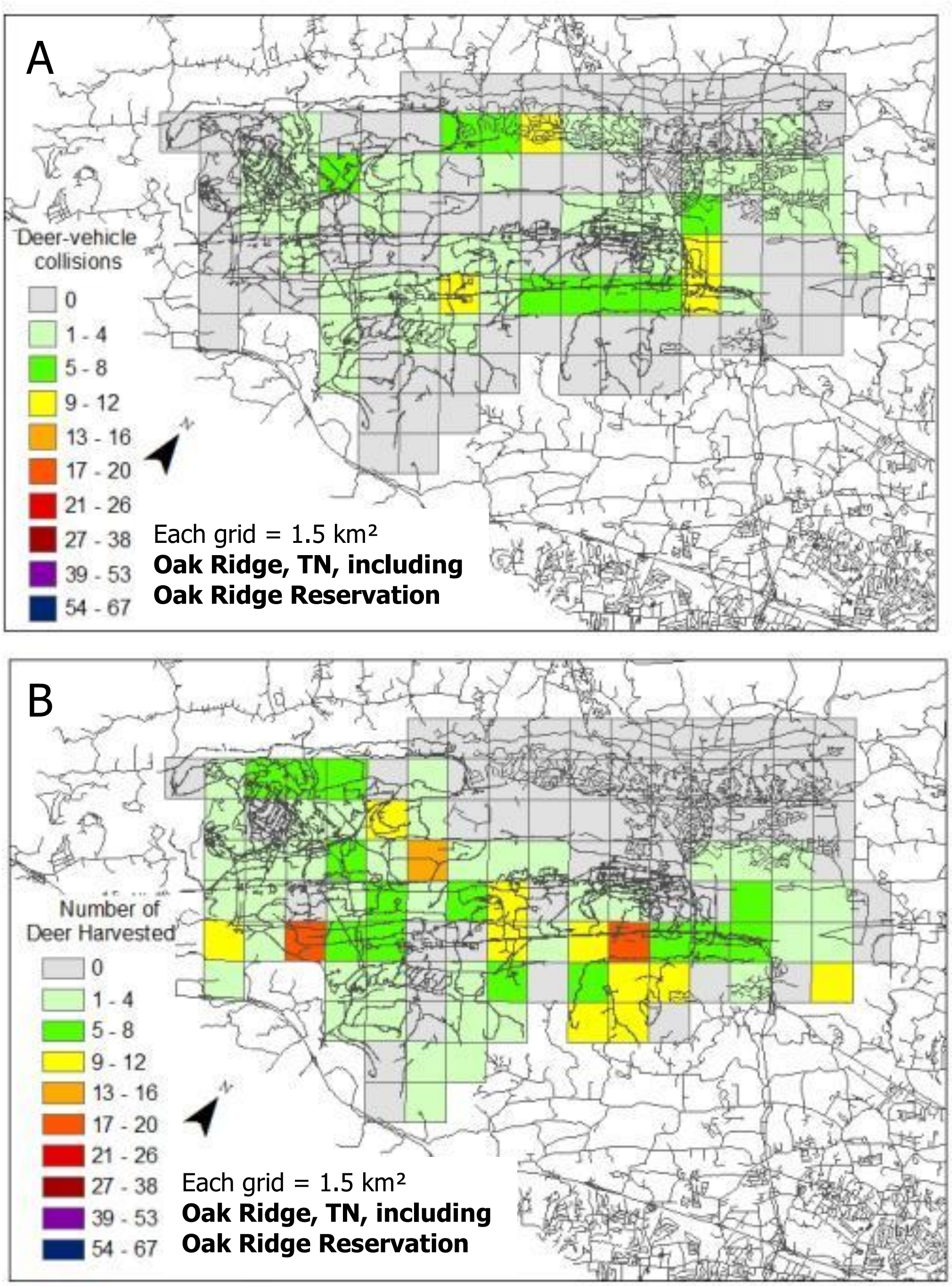


Figure 33. 1998 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

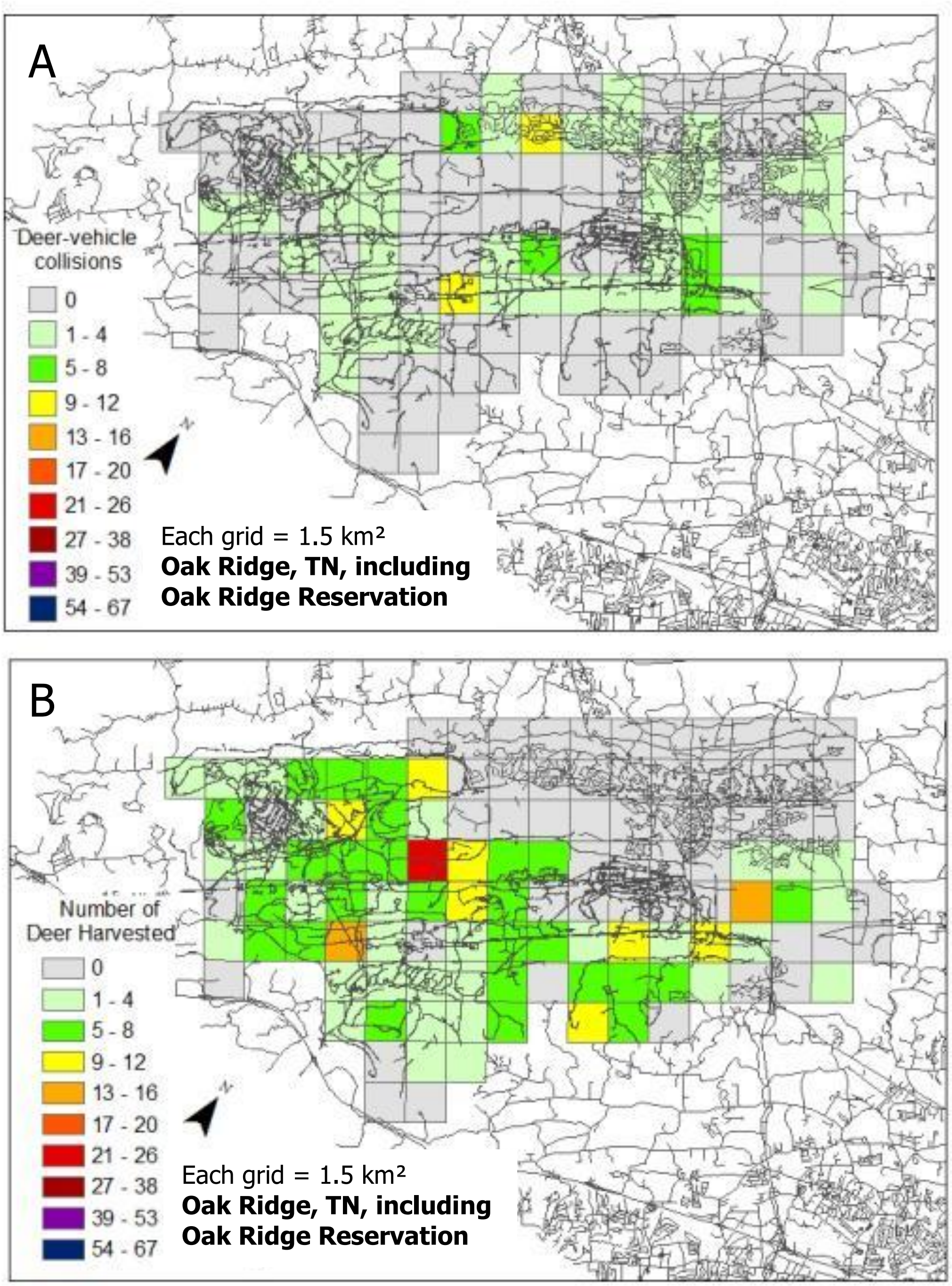


Figure 34. 1999 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

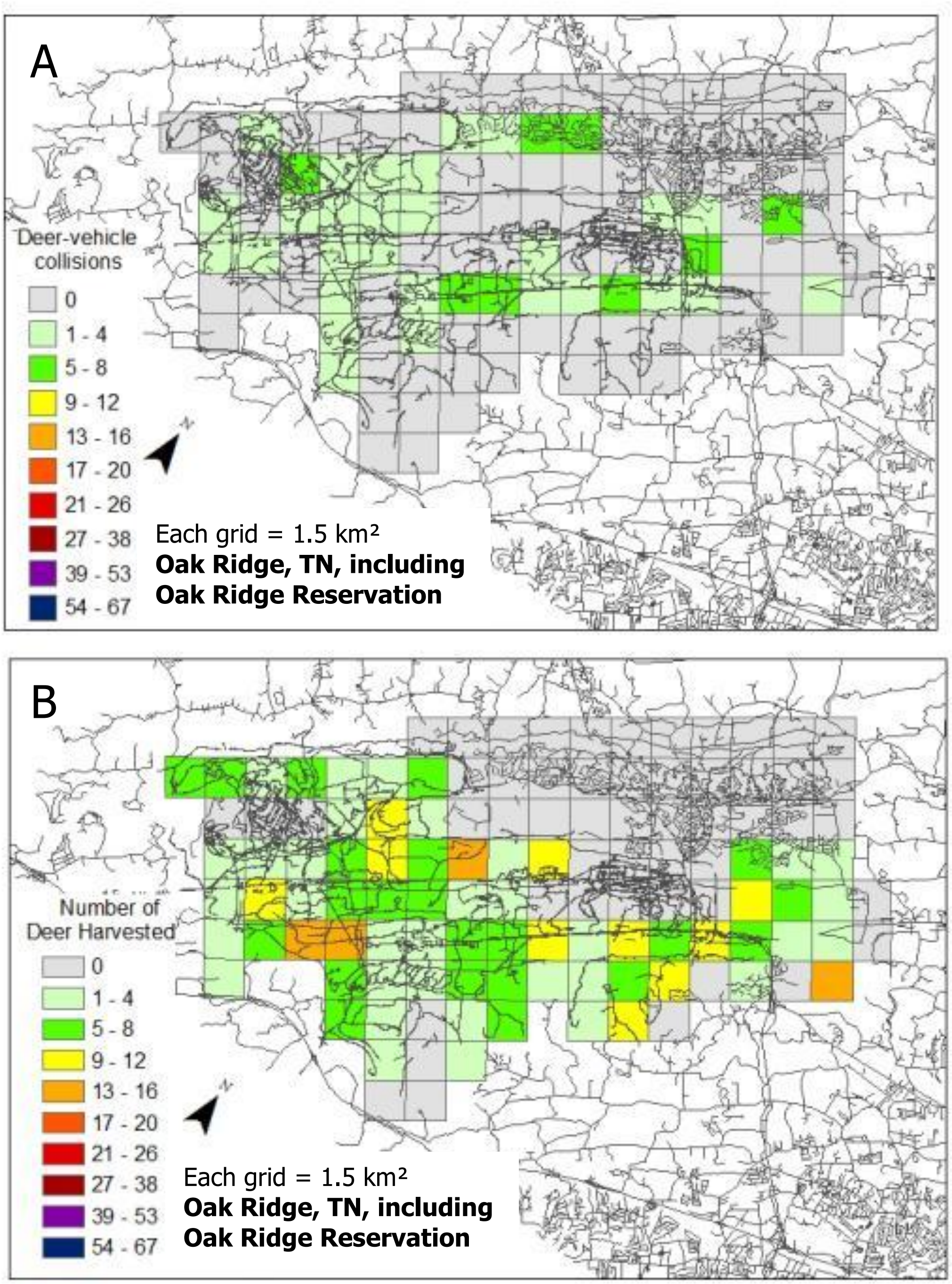
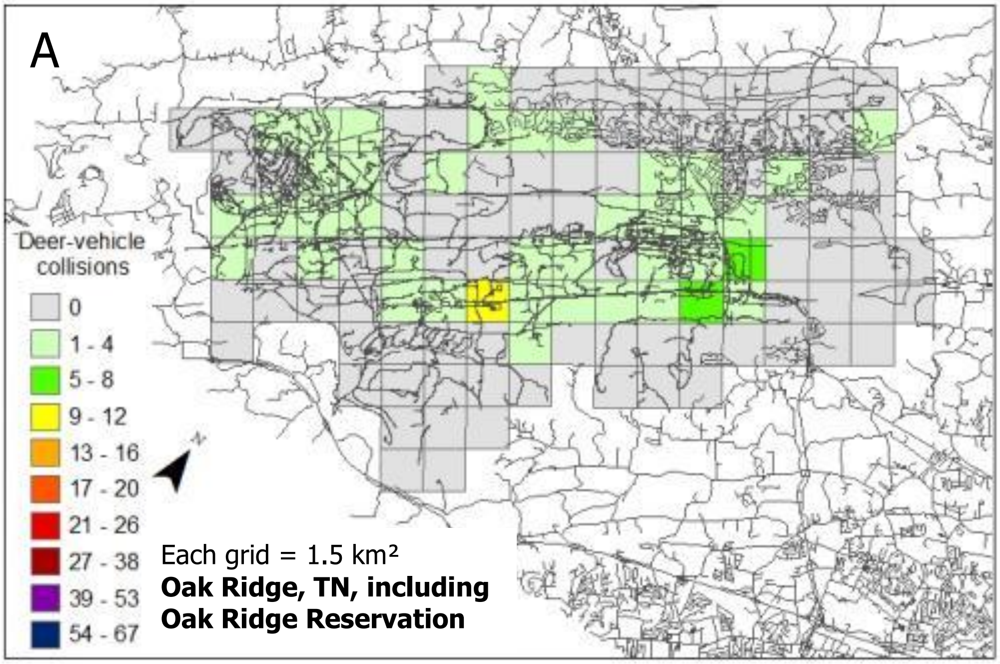


Figure 35. 2000 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.



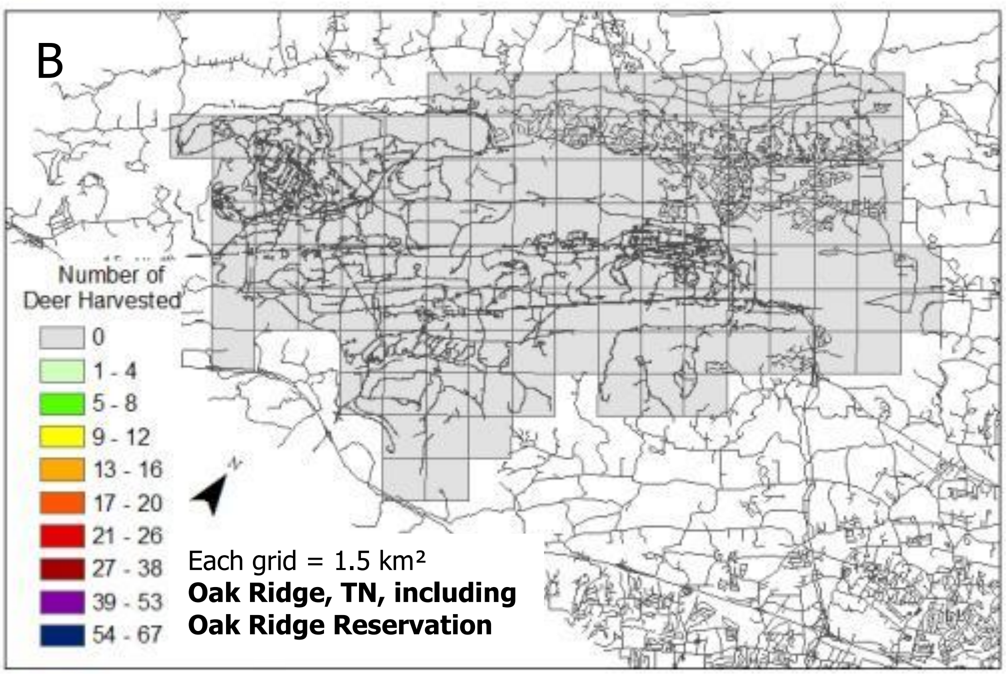


Figure 36. 2001 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. No hunting this year due to security measures.

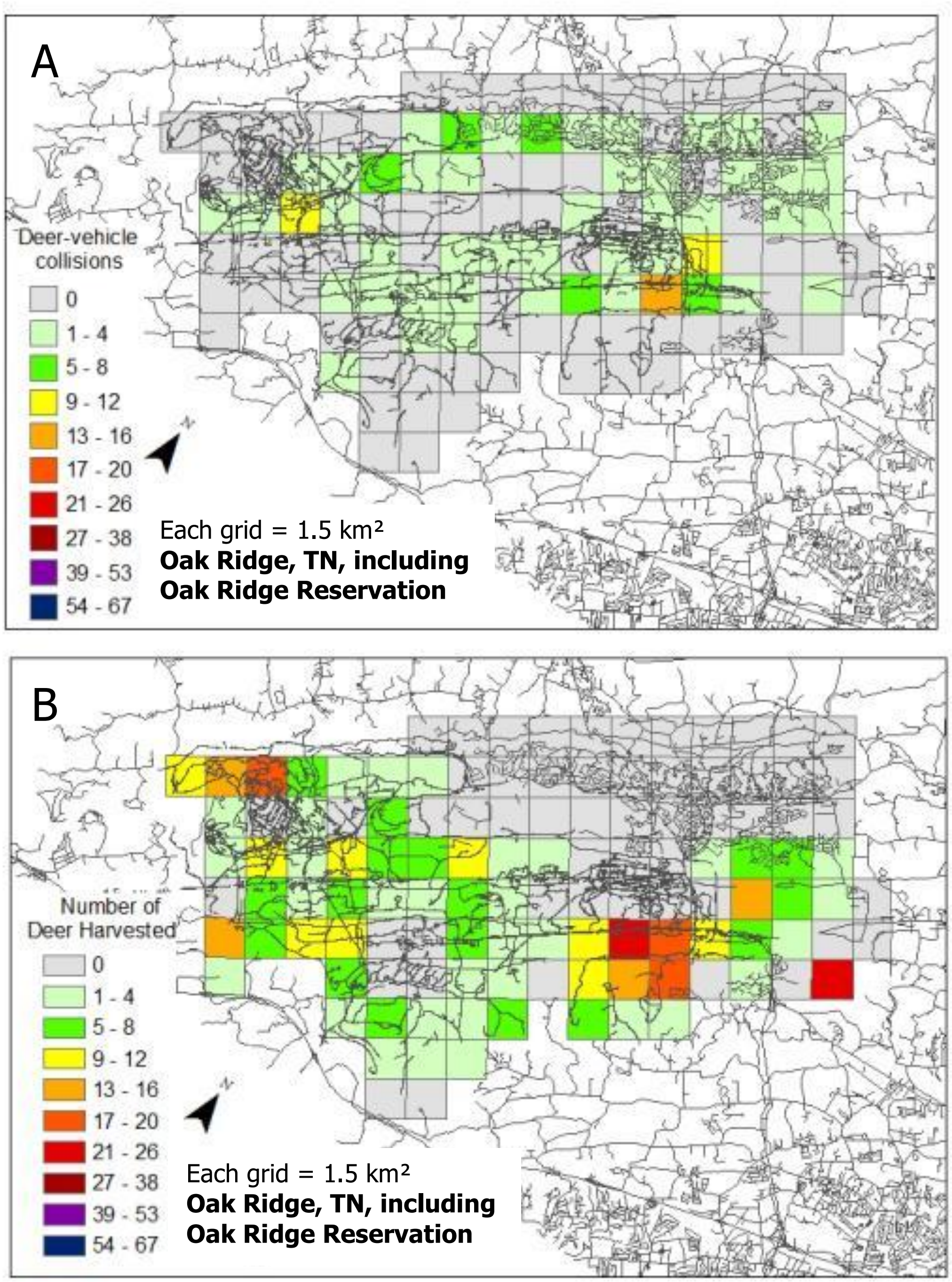


Figure 37. 2002 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

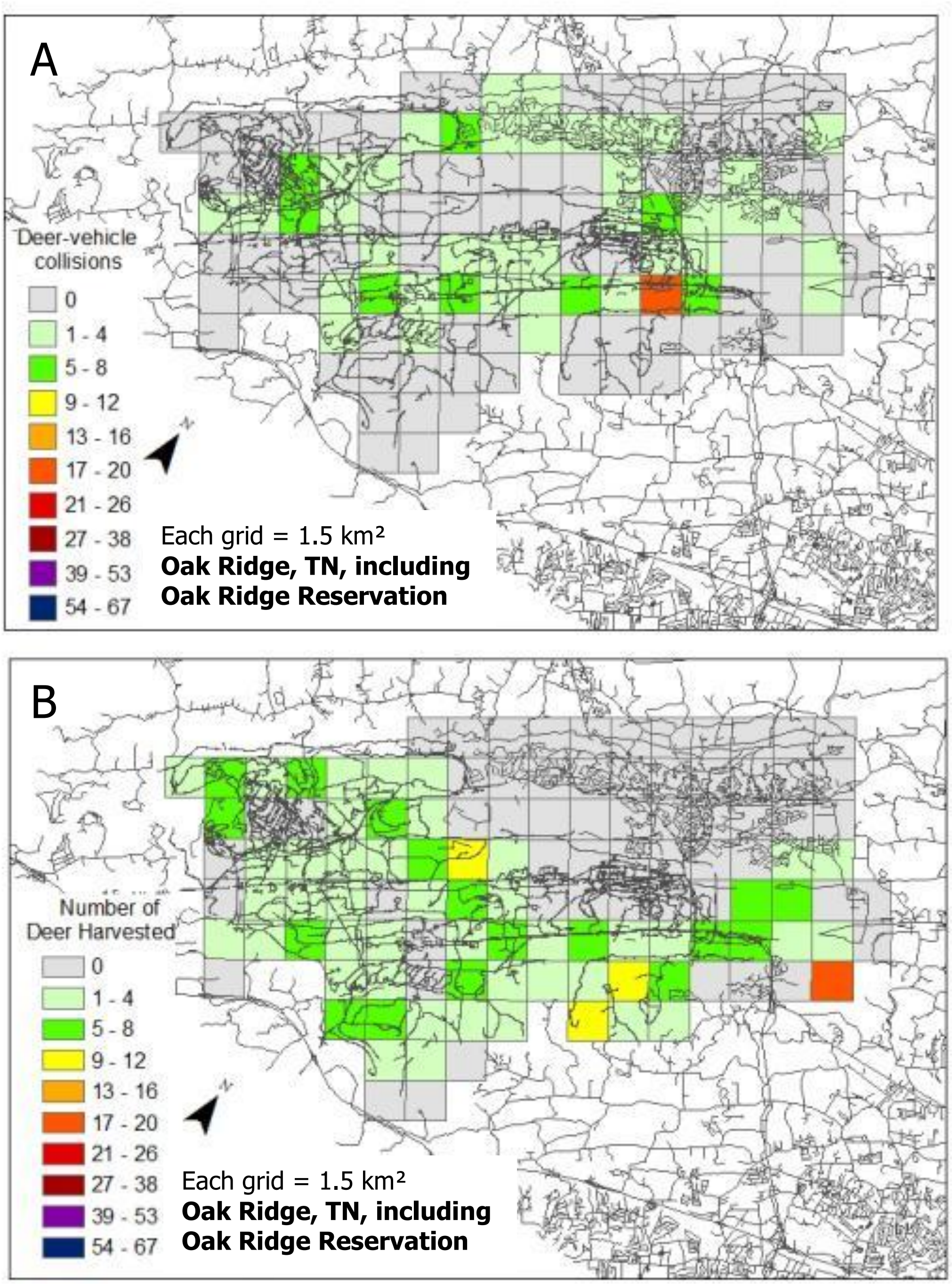


Figure 38. 2003 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

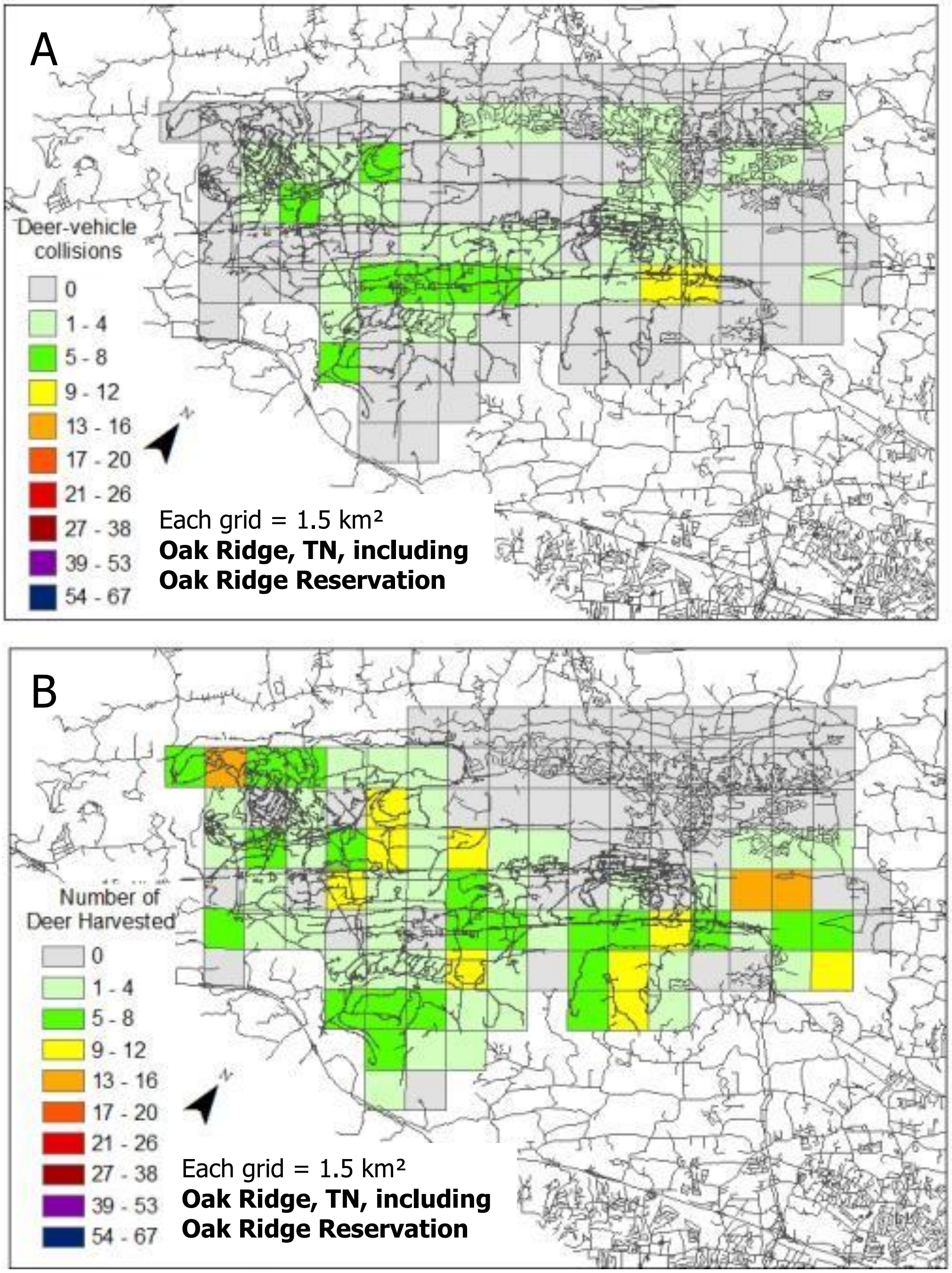


Figure 39. 2004 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

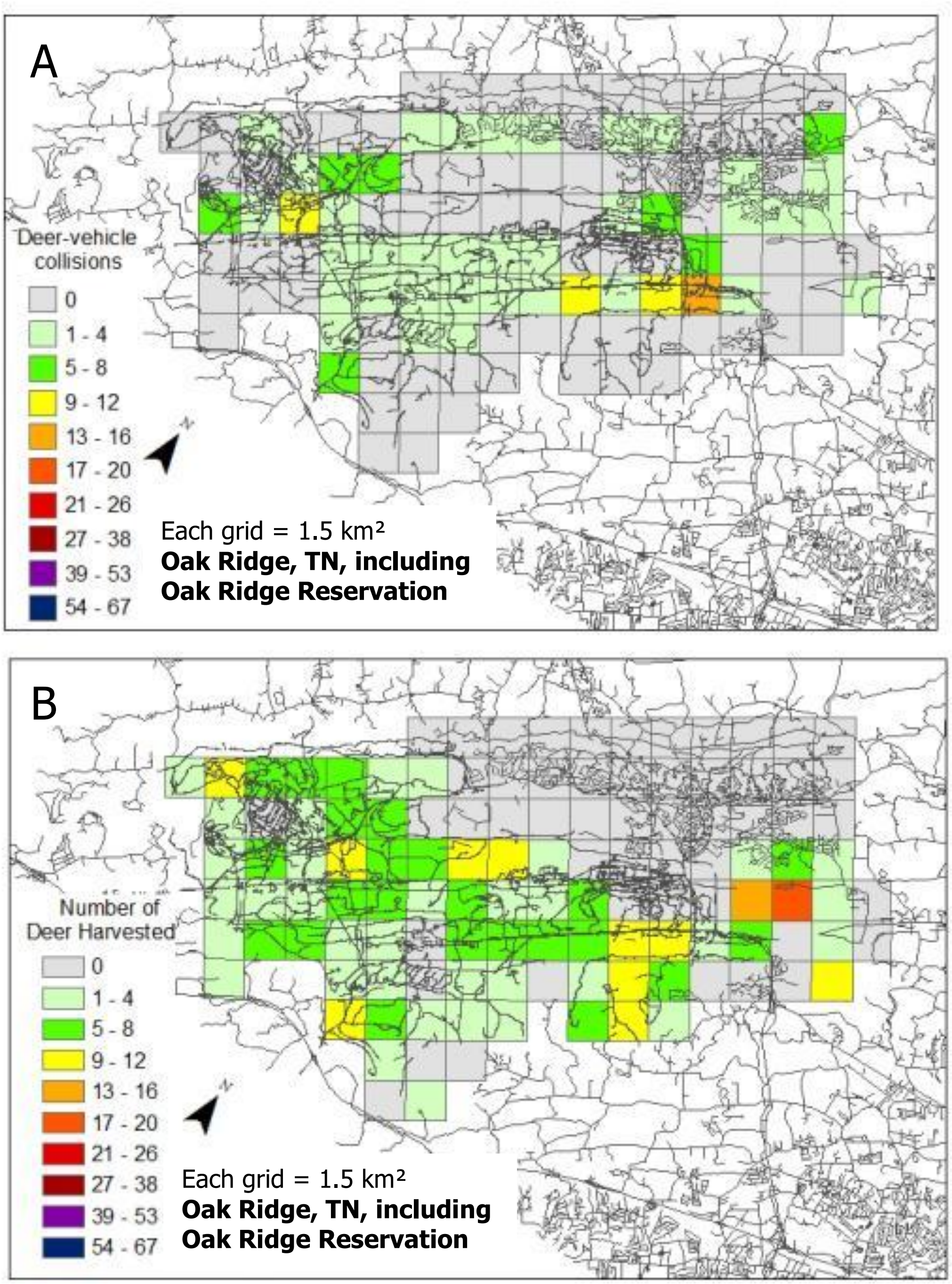


Figure 40. 2005 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

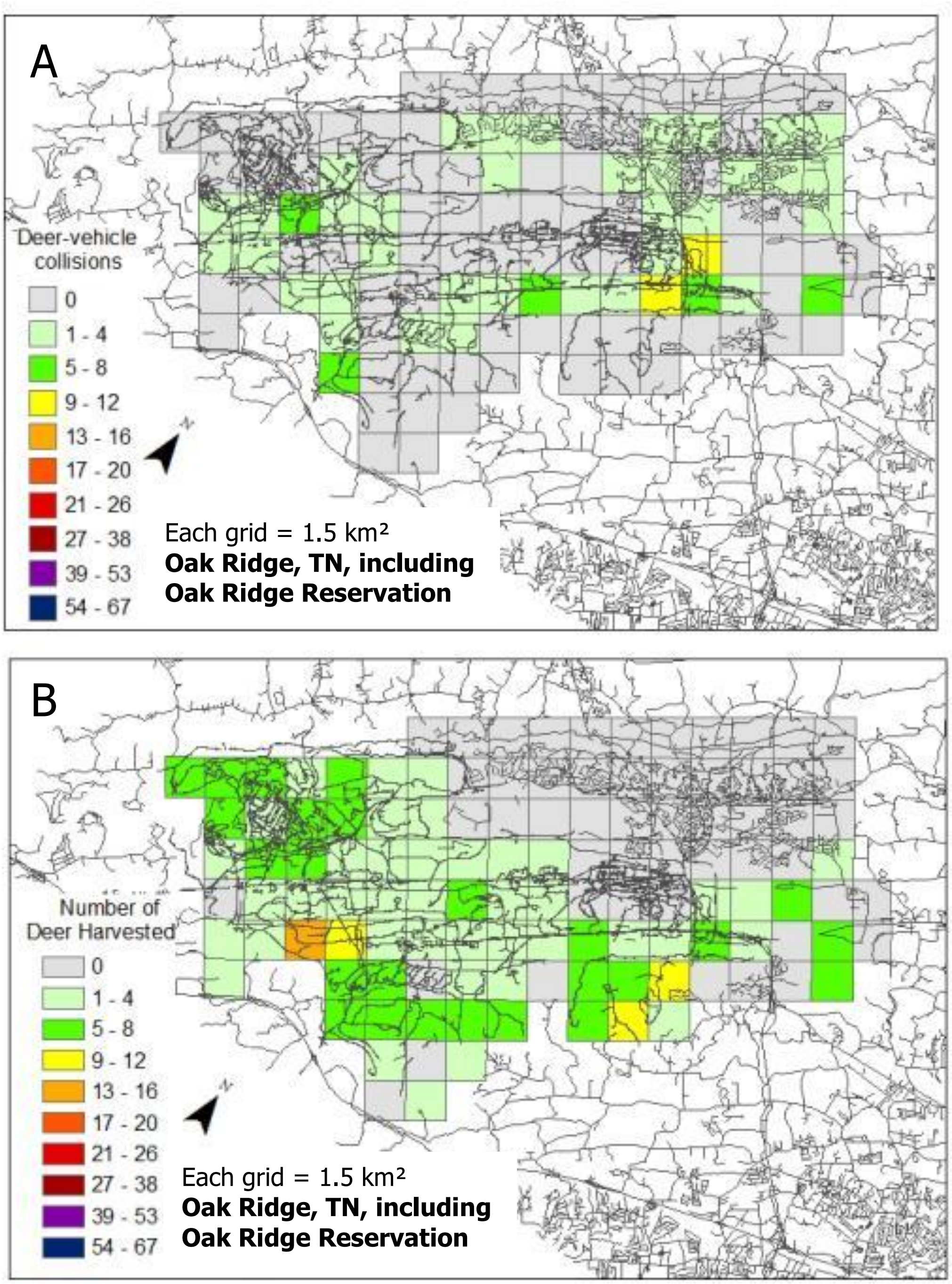
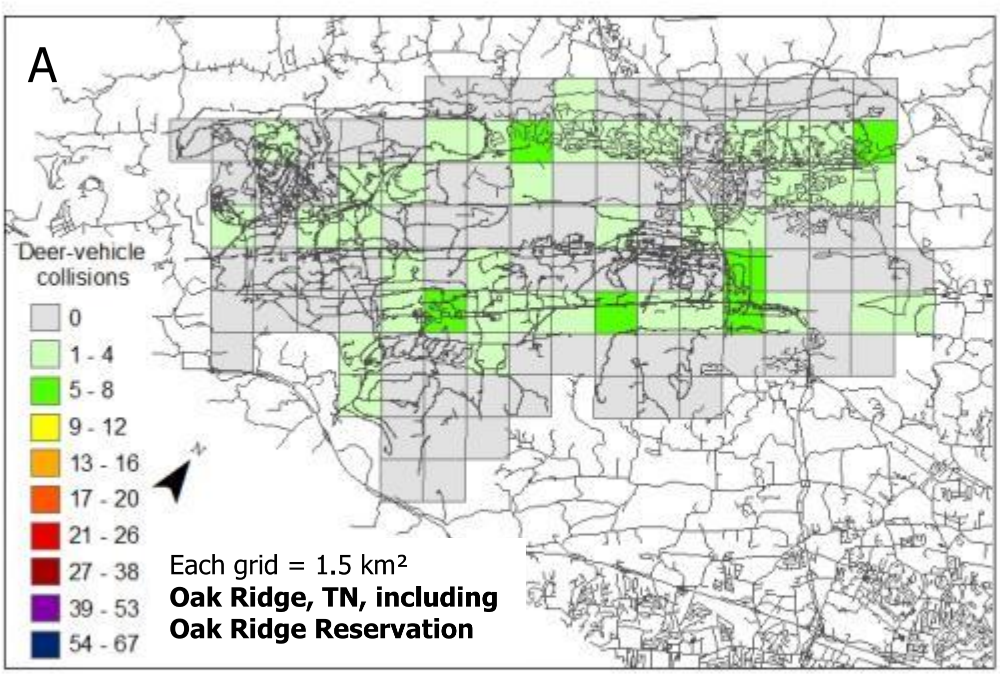


Figure 41. 2006 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.



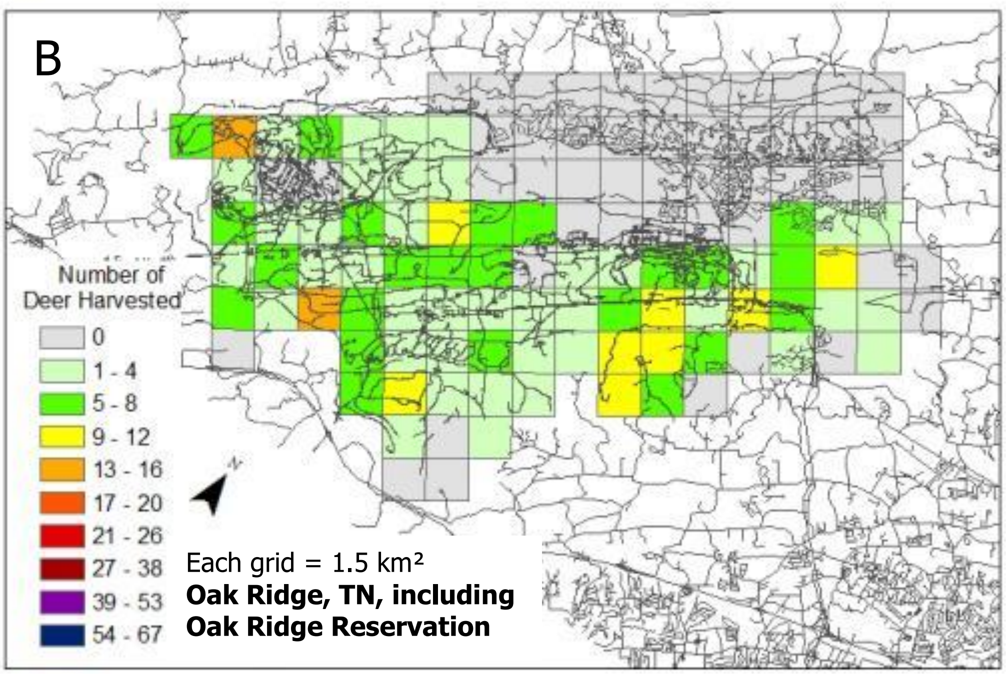


Figure 42. 2007 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

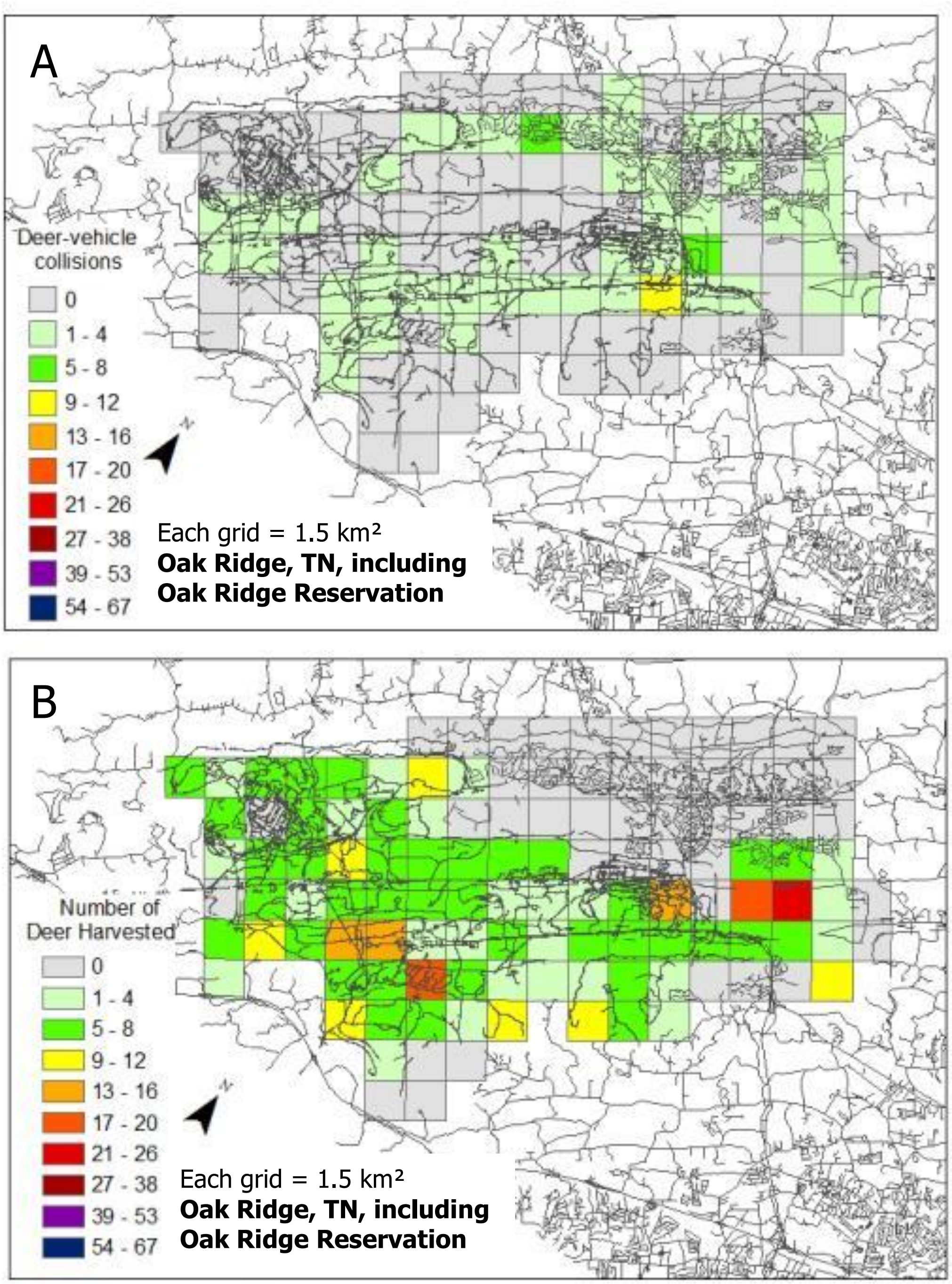


Figure 43. 2008 A) Deer-vehicle collisions in Oak Ridge, Tennessee B) deer harvested by grid on the Oak Ridge Reservation. Hunting began in 1985.

APPENDIX B

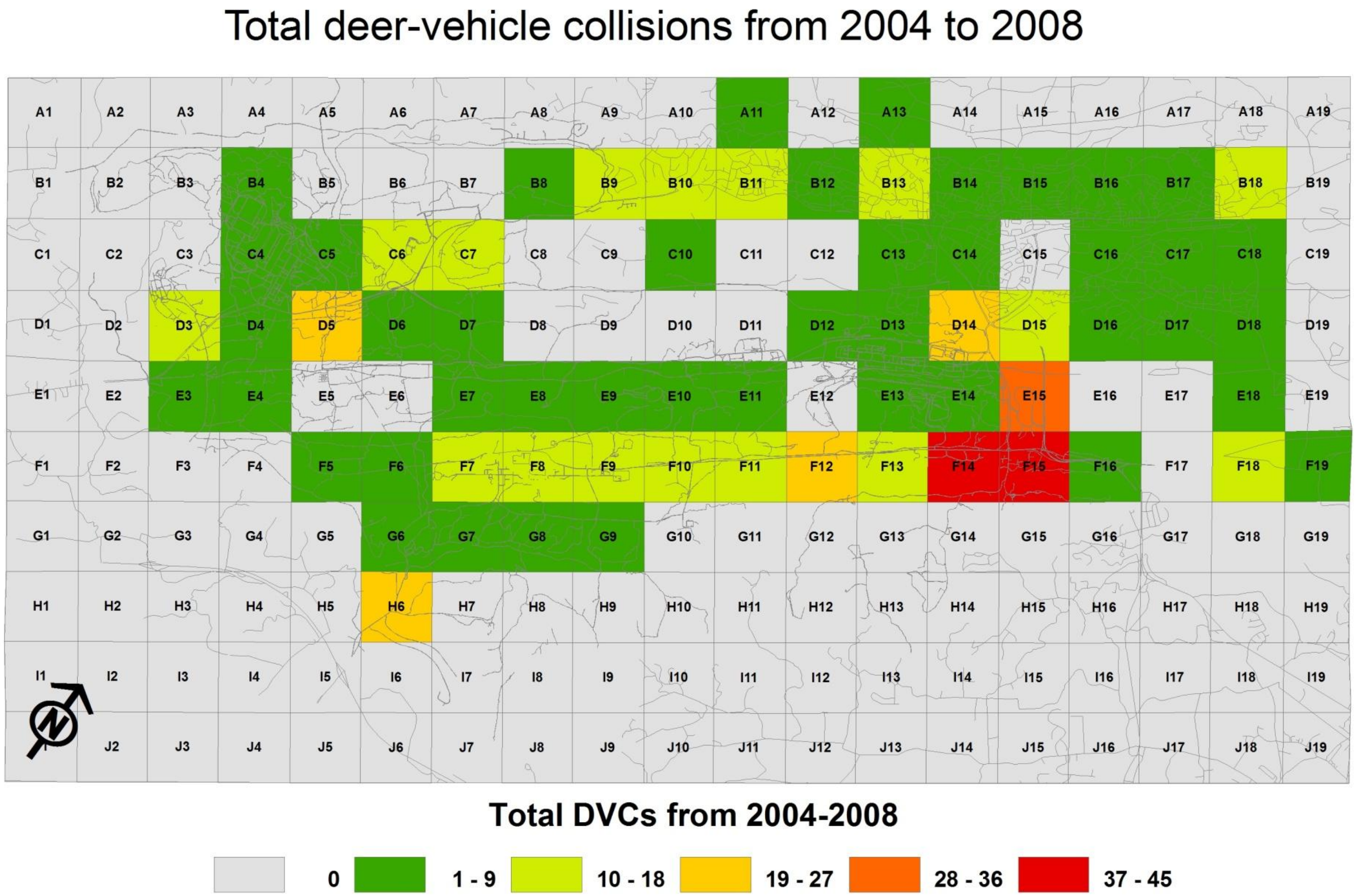


Figure 44 This figure shows which grids have had deer-vehicle collisions from 2004 to 2008, and how many total per grid.

Table 9. Data includes the percent hunted, hunting equipment permitted, total number of deer-vehicle collisions and road group designation for each grid on the Oak Ridge Reservation and surrounding area from 2004 through 2008.

Grid	%hunted 2004-2008	Equipment type	Total # DVS from 2004-2008	Road group
A01	0	n/a	0	not ORR
A02	0	n/a	0	not ORR
A03	0	n/a	0	not ORR
A04	1	both	0	not ORR
A05	3	both	0	not ORR
A06	1	both	0	not ORR
A07	0	n/a	0	not ORR
A08	0	n/a	0	LT
A09	0	n/a	0	LT
A10	0	n/a	0	LT
A11	0	n/a	1	LT
A12	0	n/a	0	HTHS
A13	0	n/a	1	HTHS
A14	0	n/a	0	LT
A15	0	n/a	0	LT
A16	0	n/a	0	LT
A17	0	n/a	0	LT
A18	0	n/a	0	LT
A19	0	n/a	0	not ORR
B01	0	n/a	0	not ORR
B02	45	both	0	LT
B03	73	both	0	LT
B04	60	both	2	LT
B05	60/ 30	both/ arch only	0	LT
B06	50	arch only	0	LT
B07	45	arch only	0	LT
B08	70	arch only	4	HTHS
B09	15	arch only	13	HTHS
B10	0	n/a	16	HTHS
B11	0	n/a	18	HTHS
B12	0	n/a	4	HTHS
B13	0	n/a	10	HTHS
B14	0	n/a	3	LT
B15	0	n/a	4	LT
B16	0	n/a	3	LT
B17	0	n/a	2	LT
B18	0	n/a	14	HTHS
B19	0	n/a	0	not ORR
C01	0	n/a	0	not ORR
C02	0	n/a	0	not ORR
C03	20.6	both	0	LT
C04	2	both	1	LT

Grid	%hunted 2004-2008	Equip type	Total # DVS from 2004-2008	Road group
C05	3/42	both/ arch only	2	LT
C06	10/50	both/ arch only	15	HTHS
C07	80	both	13	HTHS
C08	40	both	0	HTHS
C09	0	n/a	0	LT
C10	2	both	2	LT
C11	2	both	0	LT
C12	0	n/a	0	LT
C13	0	n/a	4	HTHS
C14	0	n/a	7	HTHS
C15	0	n/a	0	HTHS
C16	0	n/a	9	HTHS
C17	0	n/a	7	HTHS
C18	0	n/a	8	HTHS
C19	0	n/a	0	not ORR
D01	0	n/a	0	not ORR
D02	0	n/a	0	not ORR
D03	25/3	both/ arch only	11	HTHS
D04	50/17	both/ arch only	9	HTHS
D05	54/3	both/ arch only	26	HTHS
D06	95/3	both/ arch only	9	HTHS
D07	91.6	both	2	HTHS
D08	95	both	0	LT
D09	90	both	0	LT
D10	66	both	0	LT
D11	60	both	0	LT
D12	0	n/a	2	HTLS
D13	0	n/a	2	HTLS
D14	0	n/a	19	HTHS
D15	6	both	10	HTHS
D16	20	both	1	LT
D17	20	both	4	LT
D18	15	both	5	HTHS
D19	0	n/a	0	not ORR
E01	0	n/a	0	not ORR
E02	0	n/a	0	not ORR
E03	18	both	2	HTHS
E04	67	both	2	LT
E05	69.6	both	0	LT
E06	94	both	0	LT
E07	92	both	9	HTHS
E08	100	both	3	HTHS
E09	83	both	3	HTHS
E10	50	both	5	HTHS
E11	9.6	arch only	7	HTHS
E12	21.6	arch only	0	HTLS
E13	none until 2007 then 75%	arch only	3	HTLS

Grid	%hunted 2004-2008	Equip type	Total # DVS from 2004-2008	Road group
E14	12	arch only	6	HTLS
E15	10	both	29	HTHS
E16	48	both/ arch only	0	LT
E17	55	both	0	LT
E18	14	both	2	HTHS
E19	0	n/a	0	HTHS
F01	0	n/a	0	not ORR
F02	0	n/a	0	not ORR
F03	67	both	0	LT
F04	14	both	0	LT
F05	83.4	both	1	LT
F06	90/4	both/ arch only	8	HTHS
F07	10/65	both/ arch only	14	HTHS
F08	45	arch only	16	HTLS
F09	72	arch only	14	HTLS
F10	80	arch only	17	HTHS
F11	25/63	both/ arch only	14	HTHS
F12	70/20	both/ arch only	22	HTHS
F13	65/20	both/ arch only	10	HTHS
F14	50/20	both/ arch only	41	HTHS
F15	41	both	45	HTHS
F16	35/1	both/ arch only	8	HTHS
F17	20	both	0	HTHS
F18	43	both	10	HTHS
F19	9	both	4	HTHS
G01	0	n/a	0	not ORR
G02	0	n/a	0	not ORR
G03	10	both	0	LT
G04	0	n/a	0	not ORR
G05	3	both	0	not ORR
G06	60.4	both	7	LT
G07	35.2	arch only	1	LT
G08	21	arch only	6	LT
G09	67	arch only	5	LT
G10	44	arch only	0	LT
G11	15/5	both/ arch only	0	LT
G12	55	both	0	LT
G13	62	both	0	LT
G14	39	both	0	LT
G15	3	both	0	LT
G16	9	both	0	HTHS
G17	1	both	0	HTHS
G18	55	both	0	LT
G19	1	both	0	not ORR
H01	0	n/a	0	not ORR
H02	0	n/a	0	not ORR

Grid	%hunted 2004-2008	Equip type	Total # DVS from 2004-2008	Road group
H03	0	n/a	0	not ORR
H04	0	n/a	0	not ORR
H05	0	n/a	0	not ORR
H06	19/46	both/ arch only	23	LT
H07	96	arch only	0	LT
H08	65	arch only	0	LT
H09	63	arch only	0	LT
H10	90	arch only	0	LT
H11	7/6	both/ arch only	0	not ORR
H12	38	both	0	LT
H13	22	both	0	LT
H14	11	both	0	LT
H15	0	n/a	0	not ORR
H16	0	n/a	0	not ORR
H17	0	n/a	0	not ORR
H18	0	n/a	0	not ORR
H19	0	n/a	0	not ORR
I01	0	n/a	0	not ORR
I02	0	n/a	0	not ORR
I03	0	n/a	0	not ORR
I04	0	n/a	0	not ORR
I05	0	n/a	0	not ORR
I06	1	arch only	0	not ORR
I07	63	arch only	0	LT
I08	37.4	arch only	0	LT
I09	35	arch only	0	LT
I10	4	arch only	0	not ORR
I11	0	n/a	0	not ORR
I12	0	n/a	0	not ORR
I13	0	n/a	0	not ORR
I14	0	n/a	0	not ORR
I15	0	n/a	0	not ORR
I16	0	n/a	0	not ORR
I17	0	n/a	0	not ORR
I18	0	n/a	0	not ORR
I19	0	n/a	0	not ORR
J01	0	n/a	0	not ORR
J02	0	n/a	0	not ORR
J03	0	n/a	0	not ORR
J04	0	n/a	0	not ORR
J05	0	n/a	0	not ORR
J06	0	n/a	0	not ORR
J07	19	arch only	0	not ORR
J08	8	arch only	0	not ORR
J09	1	arch only	0	not ORR
J10	0	n/a	0	not ORR
J11	0	n/a	0	not ORR

Grid	%hunted 2004-2008	Equip type	Total # DVS from 2004-2008	Road group
J12	0	n/a	0	not ORR
J13	0	n/a	0	not ORR
J14	0	n/a	0	not ORR
J15	0	n/a	0	not ORR
J16	0	n/a	0	not ORR
J17	0	n/a	0	not ORR
J18	0	n/a	0	not ORR
J19	0	n/a	0	not ORR
			600 total	

VITA

Amanda M. Pierce attended the University of Tennessee, Knoxville where she graduated in 2000 with a Bachelor of Science degree in Wildlife and Fisheries Science. She worked several seasonal years for the National Park Service and the University of Tennessee Plant Science Department, seasonally. She then worked for the Tennessee Wildlife Resources Agency before deciding to pursue a Masters degree. She came back to the University of Tennessee in 2005, working full time in the Plant Science Department and then decided to pursue a master's degree in the fall of 2006. She received her Master of Science degree in Wildlife and Fisheries Science in August 2010.