

Monitoring Protocol and Baseline Study for White-tailed Deer  
on the Vicksburg National Military Park

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## TABLE OF CONTENTS

|                             |    |
|-----------------------------|----|
| Table of Contents.....      | i  |
| List of Tables.....         | ii |
| List of Figures.....        | iv |
| Executive Summary.....      | 1  |
| Introduction.....           | 2  |
| Objectives.....             | 3  |
| Study Area.....             | 3  |
| Methods.....                | 3  |
| Results and Discussion..... | 5  |
| Conclusions.....            | 30 |
| Recommendations.....        | 30 |
| Acknowledgements.....       | 31 |
| Literature Cited.....       | 32 |
| Appendix.....               | 35 |

## LIST OF TABLES

| <u>Tables</u>                                                                                                                                                                                                     | <u>Page</u> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| Table 1. Distance sampling results for the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.....                                                                          | 9           |
| Table 2. Distance sampling results for northern area of the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.....                                                         | 10          |
| Table 3. Distance sampling results for north-central area of the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.....                                                    | 11          |
| Table 4. Distance sampling results for south-central area of the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.....                                                    | 12          |
| Table 5. Distance sampling results for southern area of the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.....                                                         | 13          |
| Table 6. Ratio of bucks:100 does and fawns:100 does for summer 2008 on the Vicksburg National Military Park.....                                                                                                  | 14          |
| Table 7. Ratios of bucks:100 does and fawns:100 does for northern, central north, central south, and southern areas of the Vicksburg National Military Park in the summer (26 September – 30 September) 2008..... | 15          |
| Table 8. Area and number of groups by season and cover type on the Vicksburg National Military Park.....                                                                                                          | 21          |
| <b>Appendix</b>                                                                                                                                                                                                   |             |
| Table A1. Number of deer observed per night by sex and age from 26-30 September 2008 on the Vicksburg National Military Park.....                                                                                 | 36          |
| Table A2. Number of deer observed per night by sex and age from 11-15 December 2008 on the Vicksburg National Military Park.....                                                                                  | 37          |
| Table A3. Number of deer observed per night by sex and age from 3-7 March 2009 on the Vicksburg National Military Park.....                                                                                       | 38          |
| Table A4. Number of deer observed per night by sex and age from 12-15 May 2009 on the Vicksburg National Military Park.....                                                                                       | 39          |
| Table A5. Number of groups of white-tailed deer by sex and age per area from 26-30 September 2008 on Vicksburg National Military Park.....                                                                        | 40          |

|                                                                                                                                              |    |
|----------------------------------------------------------------------------------------------------------------------------------------------|----|
| Table A6. Number of groups of white-tailed deer by sex and age per area from 11-15<br>December 2008 on Vicksburg National Military Park..... | 41 |
|----------------------------------------------------------------------------------------------------------------------------------------------|----|

|                                                                                                                                         |    |
|-----------------------------------------------------------------------------------------------------------------------------------------|----|
| Table A7. Number of groups of white-tailed deer by sex and age per area from 3-7<br>March 2009 on Vicksburg National Military Park..... | 42 |
|-----------------------------------------------------------------------------------------------------------------------------------------|----|

|                                                                                                                                         |    |
|-----------------------------------------------------------------------------------------------------------------------------------------|----|
| Table A8. Number of groups of white-tailed deer by sex and age per area from 12-15<br>May 2009 on Vicksburg National Military Park..... | 43 |
|-----------------------------------------------------------------------------------------------------------------------------------------|----|

## LIST OF FIGURES

| <u>Figures</u>                                                                                                                                                                                                                                       | <u>Page</u> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| Figure 1. Mean and 95% confidence intervals (bars) of white-tailed deer density at Vicksburg National Military Park for summer (26-30 September) 2008, fall (11-15 December) 2008, winter (3-7 March) 2009, and spring (12-15 May) 2009.....         | 5           |
| Figure 2. Mean and 95% confidence intervals (bars) of white-tailed deer density by area at Vicksburg National Military Park for summer (26-30 September) 2008, fall (11-15 December) 2008, winter (3-7 March) 2009, and spring (12-15 May) 2009..... | 6           |
| Figure 3. Locations of deer by area for summer (26 – 30 September) 2008 on Vicksburg National Military Park.....                                                                                                                                     | 17          |
| Figure 4. Locations of deer by area for fall (11 – 15 December) 2008 on Vicksburg National Military Park.....                                                                                                                                        | 18          |
| Figure 5. Locations of deer by area for winter (3 – 7 March) 2009 on Vicksburg National Military Park.....                                                                                                                                           | 19          |
| Figure 6. Locations of deer by area for spring (12 – 15 May) 2009 on Vicksburg National Military Park.....                                                                                                                                           | 20          |
| Figure 7. Expected deer densities across Vicksburg National Military Park for summer (26 September - 30 September) 2008.....                                                                                                                         | 22          |
| Figure 8. Expected deer densities across Vicksburg National Military Park for fall (11 December - 15 December) 2008.....                                                                                                                             | 23          |
| Figure 9. Expected deer densities across Vicksburg National Military Park for winter (3 March - 7 March) 2009.....                                                                                                                                   | 24          |
| Figure 10. Expected deer densities across Vicksburg National Military Park for spring (12 May - 15 May 2009).....                                                                                                                                    | 25          |
| Figure 11. Visibility in summer (26 September - 30 September 2008) on Vicksburg National Military Park.....                                                                                                                                          | 26          |
| Figure 12. Visibility in fall (11 December - 15 December 2008) on Vicksburg National Military Park.....                                                                                                                                              | 27          |
| Figure 13. Visibility in winter (3 March - 7 March 2009) on Vicksburg National Military Park.....                                                                                                                                                    | 28          |

|                                                                                                 |    |
|-------------------------------------------------------------------------------------------------|----|
| Figure 14. Visibility in spring (12 May - 15 May 2009) on Vicksburg National Military Park..... | 29 |
|-------------------------------------------------------------------------------------------------|----|

## Appendix

|                                                                                                         |    |
|---------------------------------------------------------------------------------------------------------|----|
| Figure A1. Locations of deer on Vicksburg National Military Park, 26 September – 30 September 2008..... | 44 |
|---------------------------------------------------------------------------------------------------------|----|

|                                                                                                       |    |
|-------------------------------------------------------------------------------------------------------|----|
| Figure A2. Locations of deer on Vicksburg National Military Park, 11 December – 15 December 2008..... | 45 |
|-------------------------------------------------------------------------------------------------------|----|

|                                                                                               |    |
|-----------------------------------------------------------------------------------------------|----|
| Figure A3. Locations of deer on Vicksburg National Military Park, 3 March – 7 March 2009..... | 46 |
|-----------------------------------------------------------------------------------------------|----|

|                                                                                             |    |
|---------------------------------------------------------------------------------------------|----|
| Figure A4. Locations of deer on Vicksburg National Military Park, 12 May – 15 May 2009..... | 47 |
|---------------------------------------------------------------------------------------------|----|

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure A5. Locations of deer on Vicksburg National Military Park, 26 September 2008 ..... | 48 |
|-------------------------------------------------------------------------------------------|----|

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure A6. Locations of deer on Vicksburg National Military Park, 27 September 2008 ..... | 49 |
|-------------------------------------------------------------------------------------------|----|

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure A7. Locations of deer on Vicksburg National Military Park, 28 September 2008 ..... | 50 |
|-------------------------------------------------------------------------------------------|----|

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure A8. Locations of deer on Vicksburg National Military Park, 29 September 2008 ..... | 51 |
|-------------------------------------------------------------------------------------------|----|

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure A9. Locations of deer on Vicksburg National Military Park, 30 September 2008 ..... | 52 |
|-------------------------------------------------------------------------------------------|----|

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure A10. Locations of deer on Vicksburg National Military Park, 11 December 2008 ..... | 53 |
|-------------------------------------------------------------------------------------------|----|

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure A11. Locations of deer on Vicksburg National Military Park, 12 December 2008 ..... | 54 |
|-------------------------------------------------------------------------------------------|----|

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure A12. Locations of deer on Vicksburg National Military Park, 13 December 2008 ..... | 55 |
|-------------------------------------------------------------------------------------------|----|

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure A13. Locations of deer on Vicksburg National Military Park, 14 December 2008 ..... | 56 |
|-------------------------------------------------------------------------------------------|----|

|                                                                                      |    |
|--------------------------------------------------------------------------------------|----|
| Figure A14. Locations of deer on Vicksburg National Military Park, 15 December 2008  | 57 |
| Figure A15. Locations of deer on Vicksburg National Military Park, 3 March 2009..... | 58 |
| Figure A16. Locations of deer on Vicksburg National Military Park, 4 March 2009..... | 59 |
| Figure A17. Locations of deer on Vicksburg National Military Park, 5 March 2009..... | 60 |
| Figure A18. Locations of deer on Vicksburg National Military Park, 6 March 2009..... | 61 |
| Figure A19. Locations of deer on Vicksburg National Military Park, 7 March 2009..... | 62 |
| Figure A20. Locations of deer on Vicksburg National Military Park, 12 May 2009.....  | 63 |
| Figure A21. Locations of deer on Vicksburg National Military Park, 13 May 2009.....  | 64 |
| Figure A22. Locations of deer on Vicksburg National Military Park, 14 May 2009.....  | 65 |
| Figure A23. Locations of deer on Vicksburg National Military Park, 15 May 2009.....  | 66 |

## Executive Summary

Vicksburg National Military Park (VICK) required baseline data for assessing four potential alternative landscape treatments to preserve historical and cultural features as they were during the Civil War. We used white-tailed deer (*Odocoileus virginianus*) as the model species to provide baseline data for assessing effects of selected landscape treatments on natural resources. We estimated density, age and sex ratios, provided a distribution map, and produced a map of expected densities for white-tailed deer for VICK by area and park-wide for summer (July-September), fall (October-December), winter (January-March), and spring (April-June) prior to landscape treatments. Density was estimated using distance sampling by spotlighting along established roads. Ratios of age and sex were estimated based on the number of deer observed during spotlight surveys during summer. Distribution of deer was based on locations determined from spotlight surveys. Expected deer densities were provided by spatial modeling using GIS. Mean densities in summer, fall, winter, and spring were 0.099 deer per ha (95% CI: 0.072-0.136), 0.136 deer per ha (95% CI: 0.088-0.209), 0.271 deer per ha (95% CI: 0.192-0.382), and 0.159 deer per ha (95% CI: 0.117-0.218), respectively. We observed 32.9 bucks:100 does and 7.6 fawns:100 does. Deer were randomly distributed in fall (Moran's  $I = 0.10$ ,  $p = 0.32$ ), and clustered in summer (Moran's  $I = 0.36$ ,  $p = 0.04$ ), winter (Moran's  $I = 0.35$ ,  $p = 0.0003$ ) and spring (Moran's  $I = 0.51$ ,  $p = 0.007$ ). Expected deer densities varied spatially, but were greatest in the north-central and south-central areas of the park where the amount of edge was greatest.

Deer were thought to be near carrying capacity, though no evidence of over-browsing was observed. Implementation of either Alternatives C or D is expected to result in an increase in carrying capacity and be followed by an increase in deer density. Seasonal changes in density were likely related to a combination of hunting pressure and green up. Deer likely move on the VICK property during the deer hunting season and make use of the open fields and roadsides with the onset of green up.

We recommend continued monitoring of population density and reproduction, establishment of a vegetation monitoring program to assess the effects of deer density on plant composition and structure, and assessment of the adjacent land use to better understand how it affects deer distribution, especially during winter. These actions will position VICK for a better understanding of the effects of the implemented landscape alternative given its size and shape.

## INTRODUCTION

The Vicksburg National Military Park (VICK) was established in 1899 to honor the campaign and siege of Vicksburg and protect the land upon which a pivotal battle of the Civil War was fought (NPCA 2009). Vicksburg was a turning point of the Civil War when Major General Ulysses S. Grant and the Union Army defeated Lieutenant General John C. Pemberton and the Confederate soldiers (Fowler 1967). During that time, the loess ridges were too steep to be cultivated and the ravines were dominated by cane brakes and thick vegetation (Bearss 1967). In the 1930s, the Civilian Conservation Corp planted trees in an effort to control soil erosion (NPS 2009a). Today, the resulting forests, along with succession, obstruct the lines of sight that were present during the siege (NPCA 2009). It is expected visitors would gain a better understanding of the historical events during the siege if the viewscape was less limiting and more like the viewscape during the war. VICK is currently assessing four alternative landscape treatments to better preserve the historical and cultural features of the park as they were during the Civil War (NPS 2009b).

Alternative A (No-Action) continues existing management and the VICK will retain the present landscape patterns and features (Mayr 2008). Alternative B (Preservation through best management practices) requires no landscape changes, but "would take steps to protect remaining evidence of the Civil War siege" by preventing soil erosion and removing exotic plants (Mayr 2008). Alternative C (Rehabilitate/maintain areas of key military engagements) "involves removing woodland cover and maintaining the landscape in a more open and visually accessible state" (Mayr 2008), which would clear approximately 36 ha and reforest 8 – 10 ha. Alternative D (Rehabilitate/maintain the broad spectrum of military engagements) would clear approximately 141 ha of woodland cover and reforest 8 – 10 ha. Alternative C is the preferred alternative (NPS 2009b).

Natural resources will be affected if VICK adopts alternative C or D and changes the landscape. Wildlife is an important natural resource within the United States National Park system and is a management concern (Wright 1999). The VICK is charged with meeting the requirements of the National Park Omnibus Management Act of 1998 which requires a scientific study be provided for park management decisions in situations where actions may have an impact on natural resources. Requirements include the undertaking of a program of inventory and monitoring to establish baseline information to document long-term trends.

Monitoring populations for detectable changes requires estimation of the population sizes or densities. Species monitoring, relative to habitat alterations, requires a species that is common, found in the existing and proposed habitats, and is subject to sampling such that population estimates may be provided. Given deer are well studied in other national parks with a similar mission (Porter and Underwood 1999), thought to be evenly distributed throughout the VICK (Linehan 2008), respond in a predictable manner, both numerically and functionally, white-tailed deer were used as the model species for monitoring efforts to provide baseline data for a potential landscape alteration.

## OBJECTIVES

The objectives of this work were to examine density, age and sex ratios, and distribution of white-tailed deer in Vicksburg National Military Park. Specifically, we:

- 1) estimated summer (September) and fall (December) 2008 and winter (March) and spring (May) 2009 deer densities for VICK by area (see below for an area definition) and park-wide;
- 2) estimated ratios of bucks:100 does and fawns:100 does for summer 2008 for VICK by area and park-wide;
- 3) produced a distribution map of deer locations for summer and fall 2008 and winter and spring 2009 by area and park-wide; and,
- 4) produced a distribution map of expected deer densities across VICK for summer and fall 2008 and winter and spring 2009 surveys by area and park-wide.

## STUDY AREA

The Vicksburg National Military Park is located in Warren County, Mississippi, in a suburban setting east of the City of Vicksburg, Mississippi. The VICK encompasses approximately 730 ha. Elevation ranges from 47-110 m. Mean annual precipitation is 147 cm (NOAA 2008). Mean temperatures in Vicksburg, Mississippi, for summer, fall, winter, and spring were 32.0°C, 18.9°C, 16.0°C, and 26.9°C, respectively (Station 229216, NOAA 2009). Dominant overstory vegetation included oaks (*Quercus* spp.), southern sugar maple (*Acer barbatum*), and basswood (*Tilia americana*). Understory vegetation was dominated by American hornbeam (*Caprinus caroliniana*), dogwood (*Cornus florida*), redbud (*Cercis canadensis*), pawpaw (*Asimina triloba*), and sassafras (*Sassafras albidum*). Soils were of loess origin and the topography was composed of rolling hills intersected by streams and a 26 km road (Linehan 2008).

## METHODS

Deer densities were estimated for summer (July-September), fall (October-December), winter (January-March), and spring (April-June) seasons using distance sampling (Buckland et al. 1993). Seasonal densities were required to account for seasonal variation in densities. Density estimation by season was particularly important for VICK due to the size and shape of the property, as deer likely had home ranges that included areas outside the park. Seasonal densities were provided by area and park-wide. Areas were delineated by each of the road loops (northern, north-central, south-central, and southern) in the park.

Data were collected by conducting spotlighting surveys from the bed of a pickup truck while moving 8-16 km/hr along the established roads within VICK. Surveys began 0.5 hr after sunset for five consecutive nights each season except spring when surveys were conducted four consecutive nights due to prolonged adverse weather. An observer located deer using a 750,000 candlepower spotlight. Upon sighting a deer or group of deer the truck was stopped. The time, location of observer, distance to deer from the observer (m), and bearing (to the nearest degree) to the deer were recorded. If more than one deer was present the estimated center of the group was used for measuring distance and bearing. Locations were measured and recorded using a Trimble GeoXH (Trimble, Inc., Sunnydale, CA) or a Garmin Rhino 120 (Garmin, Inc.,

Olathe, KS). Distance was measured to the nearest meter using a rangefinder. Due to residential houses, businesses, and a hedge layer on one side of much of the road, a sampling fraction of 0.5 was used to represent the proportion of area surveyed. Total transect length travelled each night was 26.0 km.

Distance sampling, based on distance measurements and deer group size observations, was used to estimate deer density using program DISTANCE 5.0 (Thomas et al. 2006). Competing models were provided based on half normal, uniform, hazard rate, and negative exponential distributions. Because we did not know which distribution might best represent the data, we examined all combinations of key distributions and their associated adjustments (Buckland et al. 1993). The best model describing density was selected based on the Akaike Information Criterion (AIC; Akaike 1973) for  $\geq 60$  observations each season, and  $AIC_c$  values were used to correct for  $< 60$  observations during a season. Delta AIC values,  $\Delta AIC_c$  values where appropriate, and weights were calculated for each model each season. Precision of density estimates depend on the density, the number of transects (i.e., number of replicates), and the number of observations. In high density populations a coefficient of variation (CV), a measure of precision, can be expected to be  $< 20\%$ . The CV provides a measure of expected level of change that may be detected given landscape alterations or other management changes.

Ratios of bucks:100 does and fawns:100 does were calculated for the summer 2008 survey by area and park-wide. Across the five nights of surveying during summer the mean number of bucks, does, and fawns were calculated. The mean number of bucks and fawns were divided by the mean number of does then multiplied by 100 to calculate the ratios.

Distribution of deer was based on locations determined from spotlight surveys. Deer locations were calculated based on the known location of the observer, distance, and bearing to the deer or deer group. Deer locations were plotted using ArcMap to represent distribution. Moran's I value and the associated z-score were calculated to determine if deer were distributed in a uniform, random or clustered pattern (Anselin 2005).

A distribution map of expected deer densities for each season was calculated using ArcMap (ESRI, Redlands, CA). Densities were calculated using the Density tool in ArcGIS. For each survey night a 3 x 3 roving window was used to calculate the mean density of deer for each 100 m x 100 m cell based on location data. The mean density across each of the five nights of surveying each season was calculated. Raster data were converted to vector data and interpolated using Kriging (Kriging 1951) to provide a distribution map of expected densities. Viewshed analysis was performed in ArcMap post-hoc to quantify the areas visible from the tour road. Vegetation and elevation were accounted for using a modified version of the vegetation map provided by VICK.

## RESULTS AND DISCUSSION

### Objective 1: Deer Density Estimation

Density nearly tripled (Figure 1) from summer (0.099 deer/ha) to winter (0.271 deer/ha). In the north-central and south-central areas of the park, densities were higher in winter than in summer (Figure 2) also. The winter surveys were conducted late in the season, with the onset of green-up and visibility was at least during this season. Other nearby national parks have demonstrated a range of winter densities (Cribbs and Pietz 2008a, 2008b, 2008c), but none have seasonal data for comparison. There also are several winter density estimates for properties in the delta of Arkansas (Gregory 2005), and the East Gulf Coastal Plain of Tennessee (Dennison et al. 2008) and Mississippi (Jacobson et al. 1997). Winter densities found on VICK were within the range of densities described by Gregory (2005) and Cribbs and Pietz (2008b, 2008c), but less than those densities found on other National Park Service (NPS) properties in Arkansas (Cribbs and Pietz 2008a). Similar to densities on VICK, Jacobson et al. (1997) found deer densities of 0.14 - 0.18 deer/ha in Amite County, Mississippi.

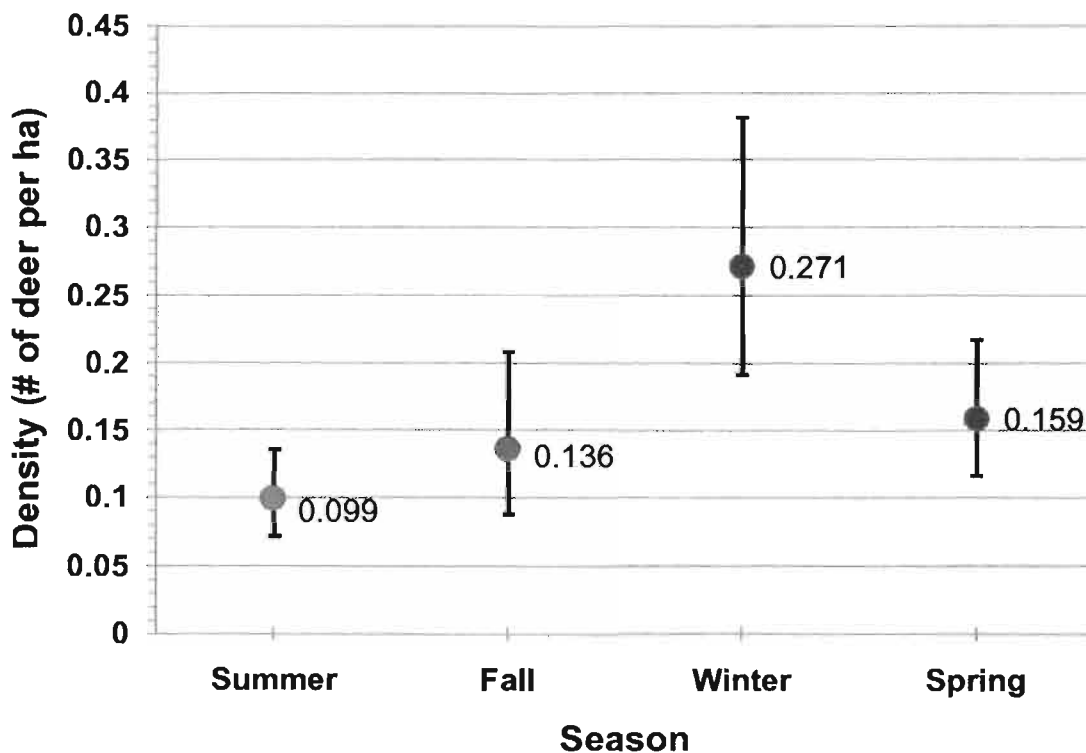


Figure 1. Mean and 95% confidence intervals (bars) of white-tailed deer density at Vicksburg National Military Park for summer (26-30 September) 2008, fall (11-15 December) 2008, winter (3-7 March) 2009, and spring (12-15 May) 2009.

NPS properties may function as refugia for deer during the hunting season and those deer populations that experience harvest pressure likely make use of the protection afforded by these properties. The deer population in and around VICK may have used

the property as a refuge during and following the hunting season which likely resulted in the greater density compared to summer.

Because the shape of the VICK is long and narrow, many deer may make use of the property as part of their home range for some portion of the year, if not year round, as home range size for deer in Mississippi has been reported to vary from 455 to 2935 ha (Mott et al. 1985). Deer density was greatest in the winter following the rut, which is estimated to peak on 28 December (MDWFP 2009). In winter visibility was least, group size was greatest, and the detection rate was least; therefore, the increase in density was more likely due to an influx of deer. We conducted surveys during late winter coincident with the beginning of green-up. Fields and manicured roadsides likely provided early forbs and grasses with high nutritional value. While we collected density data across one week each season, knowledge of how and when the VICK is used by the deer population is needed across entire seasons to better understand the process(es) driving the density patterns observed.

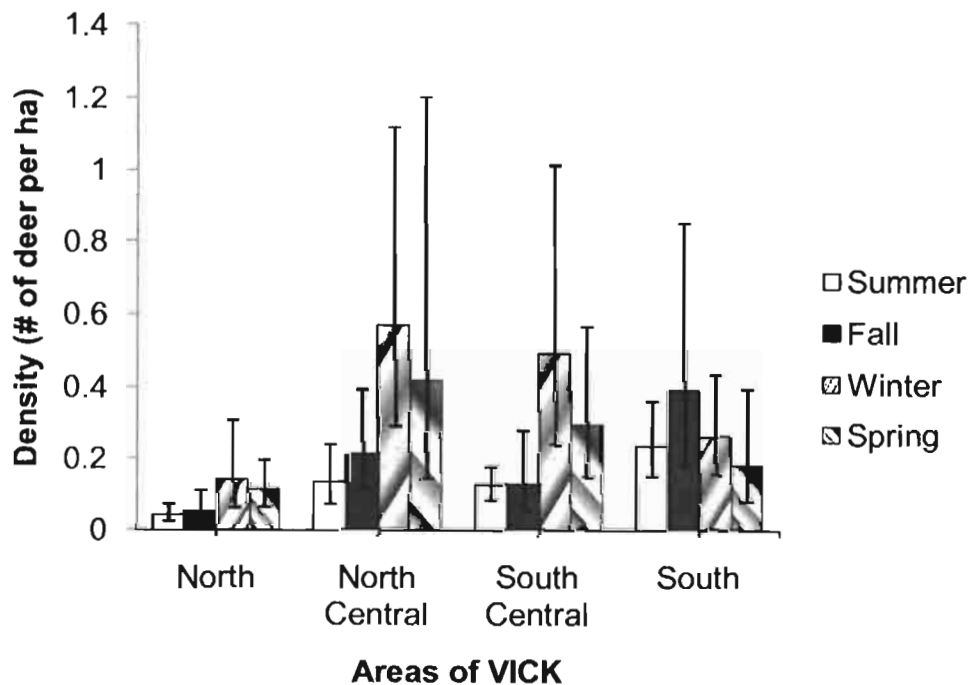


Figure 2. Mean and 95% confidence intervals (bars) of white-tailed deer density by area at Vicksburg National Military Park for summer (26-30 September) 2008, fall (11-15 December) 2008, winter (3-7 March) 2009, and spring (12-15 May) 2009.

Mixed pine/hardwoods and upland hardwoods in Mississippi were estimated to have a carrying capacity (K) of 0.056 - 0.125 deer/ha (Newsom 1984). Except for winter, when the deer population exceeded the upper end of this range, the deer population was observed to be within this range. We did not observe browse lines on the property likely

because the greatest pressure on vegetation was during the winter season when deciduous vegetation was dormant. We interpret the observed densities and lack of browse lines to indicate the deer population was near K most of the year.

At least five competing models (i.e.,  $\Delta AIC$  value  $< 2.0$ ) were identified for each season except fall which had two competing models (Table 1). In summer, all models were weighted similarly and the CV was used to select a model for future comparisons. The advantage of the half normal distribution is that the distribution has a shoulder, a feature of favorable models (Buckland et al. 1993).

The negative exponential and half normal models were equally likely ( $\Delta AIC < 2.0$ ) to provide reliable densities for fall 2008 (Table 1). Similar to summer, the negative exponential model was similar to others, but we suggest selection of the half normal model for future comparisons because of the favorable shape criterion provided by this model compared to the negative exponential model and because of its ease of interpretation.

The uniform distribution provided the best model for winter and spring 2009 (Table 1), though any of the models presented could be used for modeling density as the  $\Delta AIC$  values were  $< 2.0$ . Among the seasons, it appears the best season for providing density estimates is summer, specifically late summer as we did during this study. There are two advantages to monitoring the deer population in summer. First, the CV we observed during this season was among the lowest each season. Given the CV of the half normal or the uniform models, it should be possible to detect approximately a 30% change in the population following landscape manipulations. Second, sex ratio and reproductive data may be collected during this time of year. It should be noted that for management purposes of exploited populations sex ratio data are usually collected following the harvest season and before antlers drop. Likewise, recruitment data, not reproductive data, are collected concurrently with sex ratio data in exploited populations. Given the natural predation of deer is expected to be minimal and hunting on VICK is prohibited, recruitment should be very close to measures of reproduction.

The uniform distribution provided the best model for the northern area of the park across all seasons (Table 2). The uniform distribution provided the best model for the north-central area of the park in all seasons except winter which was best represented by the half normal distribution (Table 3). The uniform distribution provided suitable models for the south-central (Table 4) and southern areas (Table 5) of the park across all seasons. Precision for each of the areas of the VICK ranged from about 17 – 72% depending on season, with most models having a precision  $> 20\%$ .

Distance sampling requires at least 60 observations (Buckland et al. 1993) to provide models with precision sufficient to detect small changes in a population over time. We met the sample size requirement in all seasons except spring ( $n = 55$ ) and used the adjusted  $AIC_c$  to compensate for the lower number of observations. More effort is required to achieve local area densities with precision comparable to those provided for the entire property. Given our observation rates, we estimate approximately a 4-fold increase in effort would be required to achieve density estimates similar in precision to

those calculated for the entire VICK. Additionally, the cost:benefit ratio of this added effort would have to be explored further. However, we recommend using data for the entire area as it better represents the entire population.

Table 1. Distance sampling results for the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.

| Season | Key series           | Adjustment terms                                                              | CV    | AIC    | $\Delta AIC$ | $w_i$ |
|--------|----------------------|-------------------------------------------------------------------------------|-------|--------|--------------|-------|
| Summer | Negative Exponential | None                                                                          | 21.34 | 220.25 | 0.00         | 0.223 |
|        | Uniform              | cosine 1st order                                                              | 16.13 | 220.26 | 0.01         | 0.222 |
|        | Half Normal          | None                                                                          | 15.91 | 220.49 | 0.24         | 0.198 |
|        | Uniform              | simple polynomial 2nd order                                                   | 14.41 | 220.69 | 0.44         | 0.179 |
|        | Uniform              | hermite polynomial 2nd order                                                  | 14.41 | 220.69 | 0.44         | 0.179 |
| Fall   | Negative Exponential | None                                                                          | 22.18 | 198.92 | 0.00         | 0.420 |
|        | Half Normal          | None                                                                          | 19.33 | 199.87 | 0.95         | 0.261 |
|        | Uniform              | cosine 1st order                                                              | 17.64 | 201.32 | 2.40         | 0.127 |
|        | Hazard Rate          | None                                                                          | 23.42 | 201.41 | 2.49         | 0.121 |
|        | Uniform              | simple polynomial 2 <sup>nd</sup> , 4 <sup>th</sup> , & 6 <sup>th</sup> order | 20.68 | 202.49 | 3.57         | 0.071 |
| Winter | Uniform              | cosine 1st and 2nd order                                                      | 16.38 | 233.23 | 0.00         | 0.340 |
|        | Hazard Rate          | None                                                                          | 18.38 | 233.69 | 0.46         | 0.270 |
|        | Negative Exponential | None                                                                          | 19.07 | 234.30 | 1.07         | 0.199 |
|        | Half Normal          | None                                                                          | 15.95 | 234.39 | 1.16         | 0.190 |
|        | Uniform              | simple polynomial 2 <sup>nd</sup> , 4 <sup>th</sup> , & 6 <sup>th</sup> order | 17.60 | 234.60 | 1.37         | 0.171 |
| Spring | Uniform              | simple polynomial 2nd order                                                   | 15.78 | 173.44 | 0.00         | 0.221 |
|        | Uniform              | hermite polynomial 2nd order                                                  | 15.78 | 173.44 | 0.00         | 0.221 |
|        | Half Normal          | None                                                                          | 18.10 | 173.60 | 0.16         | 0.204 |
|        | Negative Exponential | None                                                                          | 23.85 | 173.82 | 0.38         | 0.183 |
|        | Uniform              | cosine 1st order                                                              | 17.68 | 173.95 | 0.51         | 0.171 |

Table 2. Distance sampling results for northern area of the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.

| Season | Key series           | Adjustment terms            | CV    | AIC <sub>c</sub> | ΔAIC <sub>c</sub> | w <sub>i</sub> |
|--------|----------------------|-----------------------------|-------|------------------|-------------------|----------------|
| Summer | Uniform              | None                        | 20.76 | 45.06            | 0.00              | 0.565          |
|        | Negative Exponential | None                        | 48.86 | 47.08            | 2.02              | 0.206          |
|        | Half-normal          | None                        | 36.33 | 47.31            | 2.25              | 0.183          |
|        | Hazard Rate          | None                        | 51.56 | 50.10            | 5.04              | 0.045          |
| Fall   | Uniform              | cosine 1st order            | 33.35 | 65.26            | 0.00              | 0.288          |
|        | Half-normal          | None                        | 35.19 | 65.40            | 0.14              | 0.269          |
|        | Negative Exponential | None                        | 42.48 | 65.69            | 0.43              | 0.232          |
|        | Uniform              | simple polynomial 2nd order | 32.09 | 65.88            | 0.62              | 0.211          |
| Winter | Uniform              | cosine 1st order            | 35.96 | 69.38            | 0.00              | 0.303          |
|        | Half-normal          | None                        | 37.81 | 69.52            | 0.14              | 0.283          |
|        | Negative Exponential | None                        | 43.80 | 69.74            | 0.36              | 0.253          |
|        | Uniform              | simple polynomial 2nd order | 35.34 | 70.66            | 1.28              | 0.160          |
| Spring | Uniform              | None                        | 25.92 | 74.03            | 0.00              | 0.328          |
|        | Half-normal          | None                        | 32.28 | 74.19            | 0.16              | 0.303          |
|        | Negative Exponential | None                        | 40.89 | 74.44            | 0.41              | 0.268          |
|        | Hazard Rate          | None                        | 28.74 | 76.39            | 2.36              | 0.101          |

Table 3. Distance sampling results for north-central area of the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.

| Season | Key series           | Adjustment terms             | CV    | AIC <sub>c</sub> | $\Delta AIC_c$ | $w_i$ |
|--------|----------------------|------------------------------|-------|------------------|----------------|-------|
| Summer | Uniform              | cosine 1st order             | 26.80 | 52.04            | 0.00           | 0.269 |
|        | Half-normal          | None                         | 30.45 | 52.05            | 0.01           | 0.267 |
|        | Uniform              | simple polynomial 2nd order  | 25.09 | 52.33            | 0.29           | 0.232 |
|        | Uniform              | hermite polynomial 2nd order | 39.90 | 52.34            | 0.30           | 0.231 |
| Fall   | Uniform              | cosine 1st order             | 30.58 | 60.56            | 0.00           | 0.285 |
|        | Half-normal          | None                         | 32.06 | 60.66            | 0.10           | 0.271 |
|        | Uniform              | simple polynomial 2nd order  | 28.39 | 60.89            | 0.33           | 0.241 |
|        | Negative Exponential | None                         | 41.74 | 61.23            | 0.67           | 0.204 |
| Winter | Negative Exponential | None                         | 33.09 | 60.32            | 0.00           | 0.441 |
|        | Half-normal          | None                         | 27.02 | 61.53            | 1.21           | 0.241 |
|        | Hazard Rate          | None                         | 33.07 | 62.07            | 1.75           | 0.184 |
|        | Uniform              | cosine 1st order             | 23.44 | 62.70            | 2.38           | 0.134 |
| Spring | Negative Exponential | None                         | 52.86 | 27.81            | 0.00           | 0.376 |
|        | Uniform              | cosine 1st order             | 37.40 | 28.96            | 1.15           | 0.212 |
|        | Uniform              | None                         | 28.01 | 28.96            | 1.15           | 0.212 |
|        | Half-normal          | None                         | 40.79 | 29.07            | 1.26           | 0.200 |

Table 4. Distance sampling results for south-central area of the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.

| Season | Key series           | Adjustment terms            | CV    | AIC <sub>c</sub> | ΔAIC <sub>c</sub> | w <sub>i</sub> |
|--------|----------------------|-----------------------------|-------|------------------|-------------------|----------------|
| Summer | Uniform              | None                        | 16.87 | 57.94            | 0.00              | 0.519          |
|        | Negative Exponential | None                        | 42.57 | 59.74            | 1.80              | 0.211          |
|        | Half-normal          | None                        | 30.45 | 59.76            | 1.82              | 0.209          |
|        | Hazard Rate          | None                        | 46.24 | 62.24            | 4.30              | 0.060          |
| Fall   | Uniform              | None                        | 34.81 | 51.50            | 0.00              | 0.413          |
|        | Negative Exponential | None                        | 52.88 | 52.24            | 0.74              | 0.285          |
|        | Half-normal          | None                        | 44.46 | 52.80            | 1.30              | 0.216          |
|        | Hazard Rate          | None                        | 71.69 | 54.65            | 3.15              | 0.086          |
| Winter | Negative Exponential | None                        | 36.19 | 72.46            | 0.00              | 0.334          |
|        | Uniform              | cosine 1st order            | 27.35 | 72.97            | 0.51              | 0.259          |
|        | Half-normal          | None                        | 29.61 | 73.07            | 0.61              | 0.246          |
|        | Uniform              | simple polynomial 2nd order | 26.56 | 73.91            | 1.45              | 0.162          |
| Spring | Uniform              | None                        | 28.29 | 41.84            | 0.00              | 0.592          |
|        | Negative Exponential | None                        | 56.61 | 44.20            | 2.36              | 0.182          |
|        | Half-normal          | None                        | 42.57 | 44.20            | 2.36              | 0.182          |
|        | Hazard Rate          | None                        | 28.29 | 47.04            | 5.20              | 0.044          |

Table 5. Distance sampling results for southern area of the Vicksburg National Military Park during summer and fall 2008, and winter and spring 2009.

| Season | Key series           | Adjustment terms             | CV    | AIC <sub>c</sub> | ΔAIC <sub>c</sub> | w <sub>i</sub> |
|--------|----------------------|------------------------------|-------|------------------|-------------------|----------------|
| Summer | Uniform              | None                         | 20.87 | 64.38            | 0.00              | 0.569          |
|        | Half-normal          | None                         | 33.06 | 66.59            | 2.21              | 0.189          |
|        | Negative Exponential | None                         | 44.70 | 66.60            | 2.22              | 0.188          |
|        | Hazard Rate          | None                         | 20.87 | 69.08            | 4.70              | 0.054          |
| Fall   | Negative Exponential | None                         | 39.46 | 58.07            | 0.00              | 0.262          |
|        | Half-normal          | None                         | 31.32 | 58.10            | 0.03              | 0.258          |
|        | Uniform              | cosine 1st order             | 28.35 | 58.17            | 0.10              | 0.249          |
|        | Uniform              | simple polynomial 2nd order  | 26.75 | 58.32            | 0.25              | 0.231          |
| Winter | Uniform              | cosine 1st order             | 25.70 | 50.52            | 0.00              | 0.297          |
|        | Half-normal          | None                         | 28.89 | 50.75            | 0.23              | 0.265          |
|        | Uniform              | simple polynomial 2nd order  | 24.34 | 51.13            | 0.61              | 0.219          |
|        | Uniform              | hermite polynomial 2nd order | 24.34 | 51.13            | 0.61              | 0.219          |
| Spring | Uniform              | None                         | 35.43 | 32.18            | 0.00              | 0.613          |
|        | Negative Exponential | None                         | 66.18 | 34.68            | 2.50              | 0.176          |
|        | Half-normal          | None                         | 50.70 | 34.68            | 2.50              | 0.176          |
|        | Hazard Rate          | None                         | 38.80 | 37.90            | 5.72              | 0.035          |

## Objective 2: Sex and Age Ratio Estimation

Ratios of bucks:100 does and fawns:100 does were determined for summer (Table 6) only; distinguishing age and sex in the other seasons was not possible due to dropped antlers and near-adult sized fawns. The south-central area of the park had the greatest number of bucks per 100 does and fawns per 100 does (Table 7). In providing age and sex ratios, the assumption that the observability of the age and sex categories were equal (Lancia et al. 2000) was made.

The sex ratio was indicative of populations found in urban settings (Swihart et al. 1993). A low number of bucks per 100 does (e.g., < 25) is often thought to be indicative of a population that has lost bucks either through natural processes, such as disease or predation, or harvest. Low numbers of bucks per 100 does results in more energy expended per male for breeding, and this results in a poorer condition of males following the rut and an extended breeding season. Greater numbers of males per 100 does results in less time invested in tending does, better overall survival, and a shorter breeding season (Gruver et al. 1984, Mysterud et al. 2002). VICK, which may act as a refuge for deer, would be expected to have a greater percentage of bucks than the surrounding suburban and rural areas that are subject to hunting.

The fawn:100 does ratio was extremely low and indicative of a population at or near K. Kie and White (1985) describe a white-tailed deer population that ranged widely in the number of fawns per doe, from 13 fawns:100 does to 72 fawns:100 does. They concluded a relationship existed among rainfall, forage quantity and quality, density, predation, and fawn survival. Overall, fawn survival decreased with an increase in population density and a decrease in rainfall. While rainfall on VICK is not likely a factor driving population dynamics of deer, forage quantity and quality may be. More importantly, density relative to forage quantity and quality is unknown on VICK, but may be the factors driving the ratios we observed.

Similar to density estimates, we suggest using the population ratios because of the nature of the shape and size of the VICK and the focus on the population as the unit of management.

Table 6. Ratio of bucks:100 does and fawns:100 does for summer 2008 on the Vicksburg National Military Park.

| Season | Bucks:100 Does | Fawns:100 Does | Total Observations* |
|--------|----------------|----------------|---------------------|
| Summer | 32.9           | 7.6            | 111                 |

\*Only includes observations of known sex or age.

Table 7. Ratios of bucks:100 does and fawns:100 does for northern, north-central, south-central, and southern areas of the Vicksburg National Military Park in the summer (26 September – 30 September) 2008.

| Area          | Bucks:100 Does | Fawns:100 Does | Total Observations* |
|---------------|----------------|----------------|---------------------|
| Northern      | 50.0           | 0.0            | 18                  |
| North-Central | 55.6           | 11.1           | 15                  |
| South-Central | 73.3           | 20.0           | 29                  |
| Southern      | 9.3            | 7.6            | 49                  |

\*Only includes observations of known sex or age.

### Objective 3: Spatial Distribution

We observed 69 groups of deer (Figure A1, A5-A9) with a mean group size of 2.0, totaling 136 deer in the summer (Table A1, Table A5) with a clustered spatial pattern (Moran's  $I = 0.36$ ,  $p = 0.04$ ; Figure 3). In the fall we observed 75 groups of deer (Figure A2, A10-A14) with a mean group size of 2.0, totaling 150 deer (Table A2, Table A6), and randomly distributed (Moran's  $I = 0.10$ ,  $p = 0.32$ ; Figure 4). A total of 300 deer and 86 groups (Figure A3, A15-A19) demonstrated a clustered pattern (Moran's  $I = 0.35$ ,  $p = 0.0003$ ) in winter (Table A3, Table A7) with a mean group size of 3.5 (Figure 5). In spring, we observed 55 groups of deer (Figure A4, A20-A23) with a mean group size of 3.1, totaling 172 deer (Table A 4, Table A8), and showing a clustered spatial pattern (Moran's  $I = 0.51$ ,  $p = 0.007$ ; Figure 6).

Linehan et al. (2008) described deer to be evenly distributed throughout the VICK, a pattern we did not observe. Our results indicated a clustered spatial pattern among deer groups throughout three seasons. We used different methods than Linehan et al. (2008) and this could be the source of differing results. They used cameras and deer sign to assess the distribution of deer in the park. Our results, however, are more consistent with the biology and ecology of the species (Main and Coblentz 1990).

White-tailed deer demonstrate sexual segregation, like other ungulates (Bowyer 1984, Main and Coblentz 1990, Bleich et al. 1997), wherein each sex forms independent groups throughout the year with the sexes coming together primarily during the breeding season. The breeding behavior, which includes males chasing and checking for females in estrous, was the likely source of the random distributional pattern we observed in the fall.

In no season did we observe deer in cover types as expected (i.e., in proportion to their availability;  $P < 0.05$ ; Table 8). Visibility differed by cover type and this likely played a role in our results related to observations in expected and available cover types. However, observing different proportions of deer in the various cover types also supports the spatial patterns observed.

#### Objective 4: Expected Deer Densities

Expected densities across VICK for summer and fall 2008 were highest in the south-central and southern areas (Figures 7-10). Expected deer densities across VICK appeared related to increasing visibility.

Visibility was limited by vegetation, and topography to a lesser degree, with a mean visibility of 40.3% ( $\pm 1.7\%$  SD) each season (Figures 11-14). Visibility was greatest closer to the road and in association with grasslands. Because deer were not evenly distributed, were not observed in proportion to the availability of cover types, and demonstrated greater densities in areas of greater visibility, we recommend stratifying data collection by habitat type in future efforts to improve deer density estimates and distributional patterns if resources allow.

A rule of thumb for deer home ranges is that an average deer covers about 2.56 km<sup>2</sup>. It is unlikely that many deer have a home range exclusively within the boundary of VICK. As a result it is important to understand the land uses and changes of the surrounding environment when interpreting local density expectations.

Under Alternatives A or B the deer density will likely continue along the current trajectory. However, the current trajectory of the deer population is unknown. Methods used in this study will provide a beginning point for assessing the population trajectory, regardless of the alternative implemented.

Under Alternative C, the preferred alternative (NPS 2009b), the deer density is expected to increase as a whole and in the central and southern portions of the park specifically. Deer favor edge habitats where the diversity of forage is greatest and this option is expected to provide a favorable mix of cover types. Much of the cover provided by forests in the southern half of the park will be removed. Currently, the southern area likely limits the movement of deer to the southeast or southwest. The southeast and southwest sides of the southern area are bounded by development and the interstate. This likely serves as a sufficient barrier to movement. The northwest side of the southern area is bounded by development, though there is some acreage adjacent to the park that still provides "natural" habitat. The north-central and south-central areas are expected to experience a slight increase in deer density given implementation of Alternative C. The northern area is not expected to experience much of change in local densities.

Immediately following the alteration and assuming no development occurs outside the boundaries of VICK, there is expected to be an increase in deer density across the VICK as a whole under Alternative D. In the long-term, while we would expect an overall increase in density, we expect a slight decline in local densities in the southern areas. Changing land use of property adjacent to VICK is expected to play a major role of how deer densities in VICK fluctuate over time.

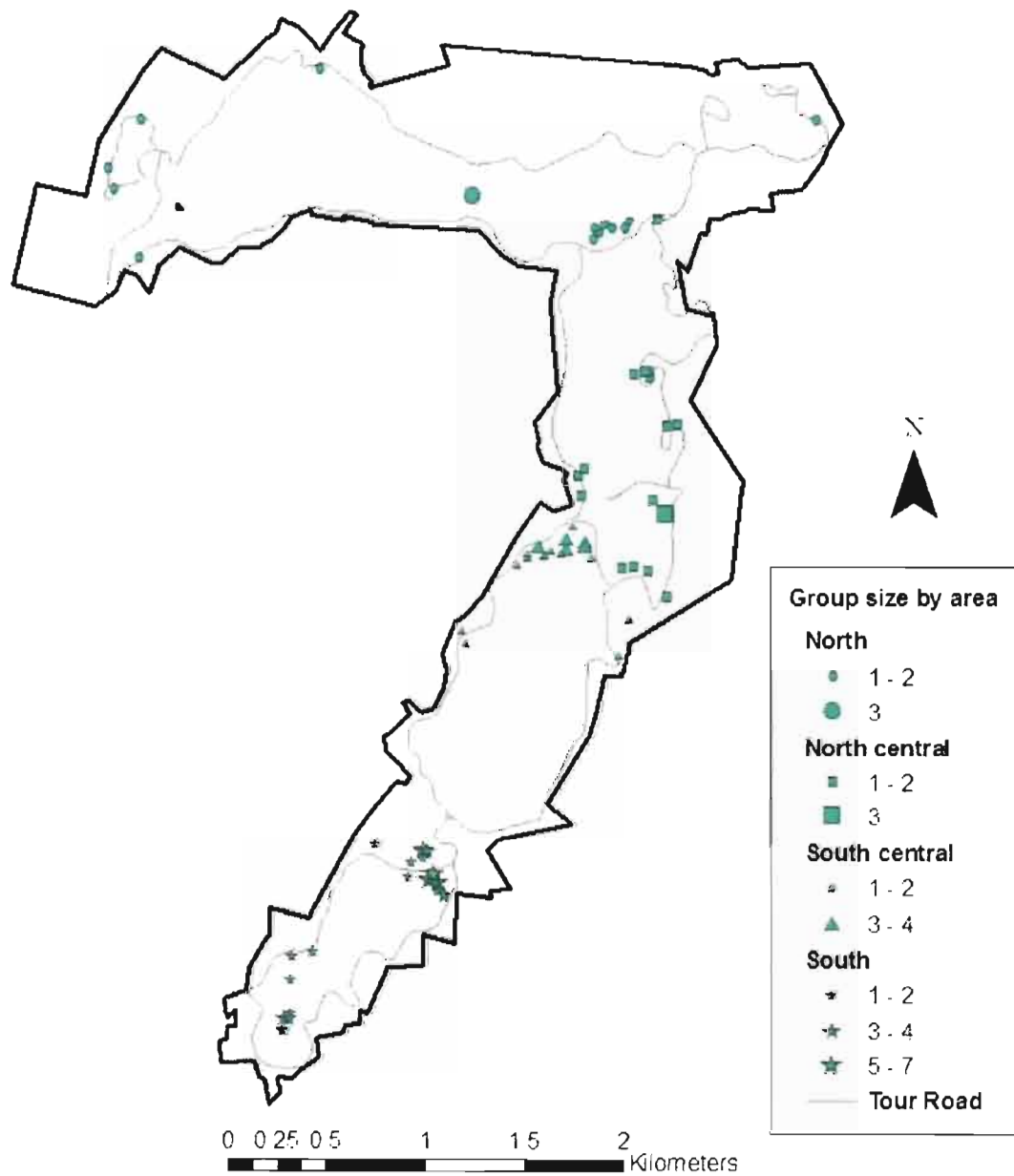


Figure 3. Locations of deer by area for summer (26 – 30 September) 2008 on Vicksburg National Military Park.

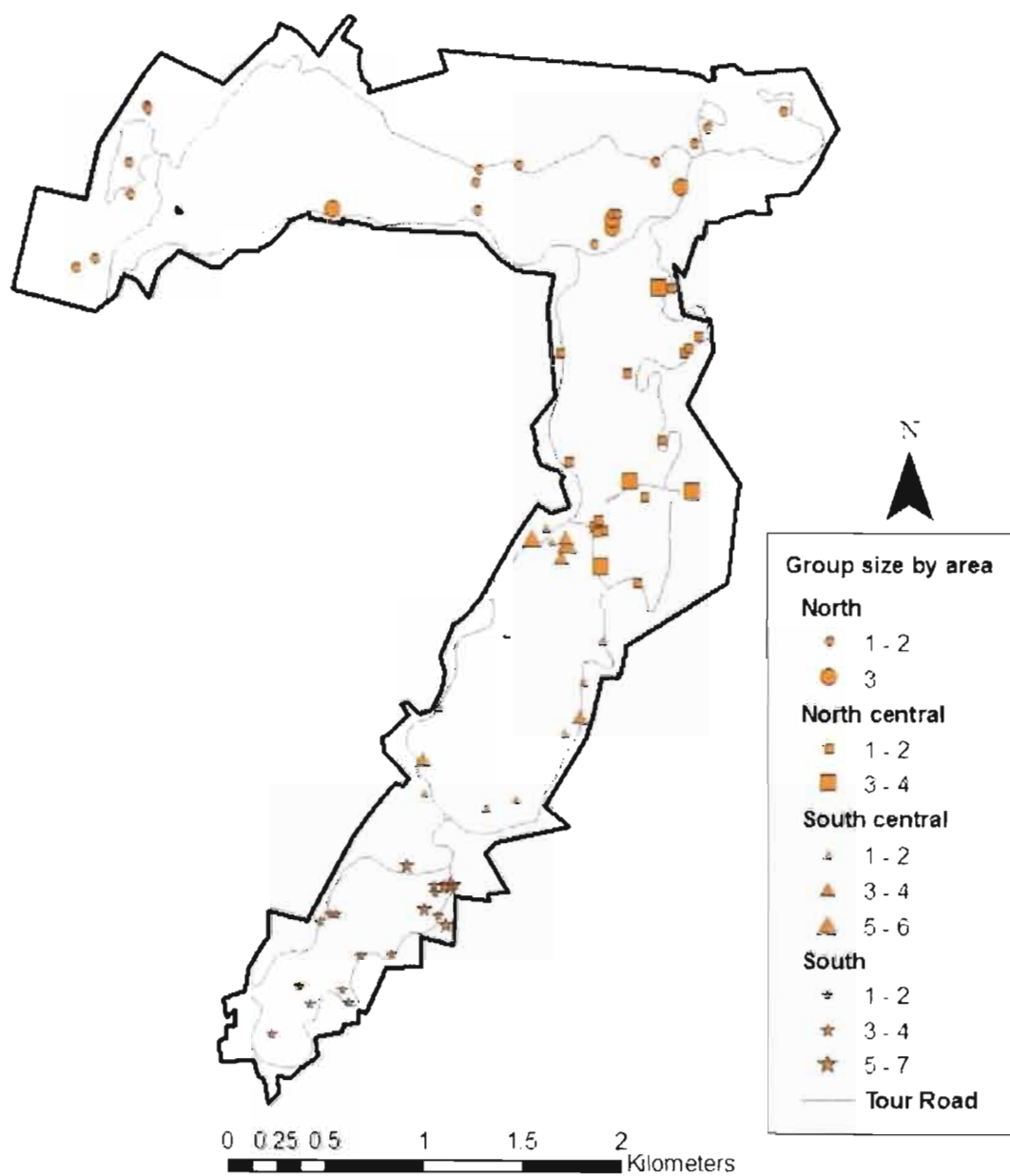


Figure 4. Locations of deer by area for fall (11 – 15 December) 2008 on Vicksburg National Military Park.

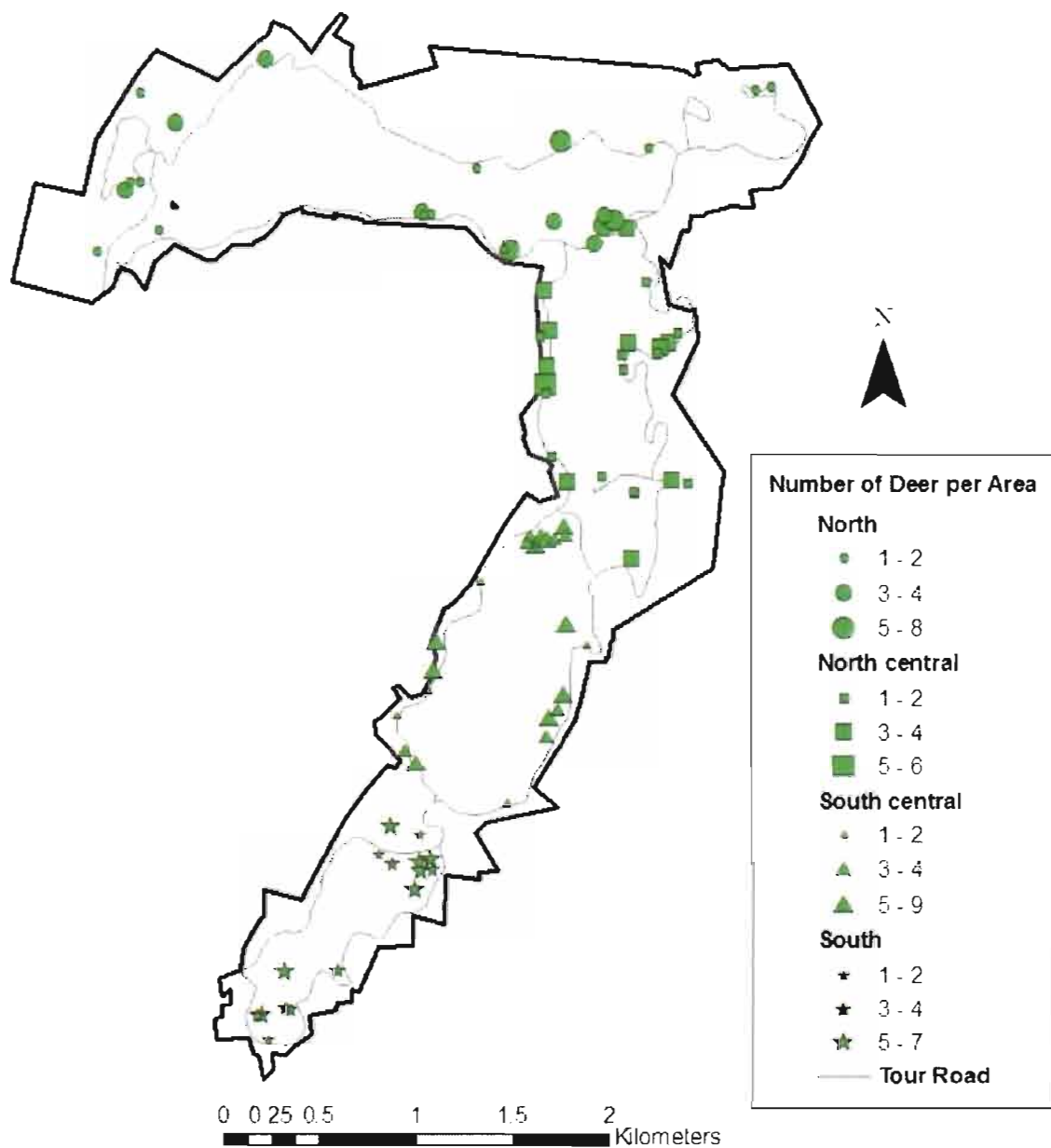


Figure 5. Locations of deer by area for winter (3 – 7 March) 2009 on Vicksburg National Military Park.

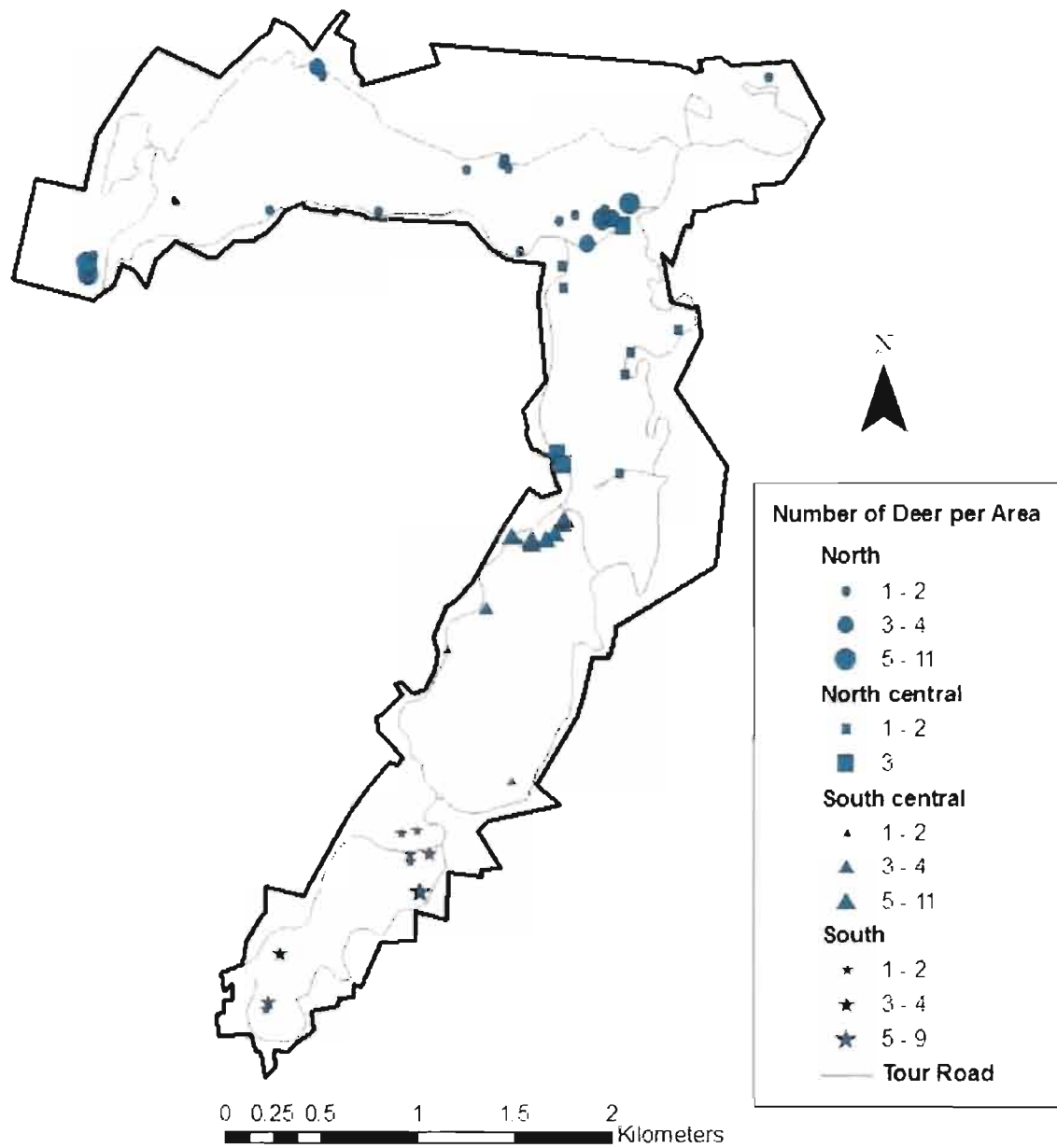


Figure 6. Locations of deer by area for spring (12 – 15 May) 2009 on Vicksburg National Military Park.

Table 8. Area and number of groups by season and cover type on the Vicksburg National Military Park.

| Season | Cover Type    | Area (ha) | % Area for<br>Entire Park<br>(ha/total) | # Groups<br>per Cover<br>Type | % Groups<br>per Cover<br>Type<br>(# deer/total) |
|--------|---------------|-----------|-----------------------------------------|-------------------------------|-------------------------------------------------|
| Summer | Forested Area | 486.3     | 68.6                                    | 13                            | 18.8                                            |
|        | Grassland     | 133.5     | 18.8                                    | 46                            | 66.7                                            |
|        | Other         | 89.0      | 12.6                                    | 10                            | 14.5                                            |
| Fall   | Forested Area | 486.3     | 68.6                                    | 28                            | 37.3                                            |
|        | Grassland     | 133.5     | 18.8                                    | 41                            | 54.7                                            |
|        | Other         | 89.0      | 12.6                                    | 6                             | 8.0                                             |
| Winter | Forested Area | 486.3     | 68.6                                    | 30                            | 34.8                                            |
|        | Grassland     | 133.5     | 18.8                                    | 49                            | 57.0                                            |
|        | Other         | 89.0      | 12.6                                    | 7                             | 8.2                                             |
| Spring | Forested Area | 486.3     | 68.6                                    | 7                             | 12.7                                            |
|        | Grassland     | 133.5     | 18.8                                    | 33                            | 60.0                                            |
|        | Other         | 89.0      | 12.6                                    | 15                            | 27.3                                            |

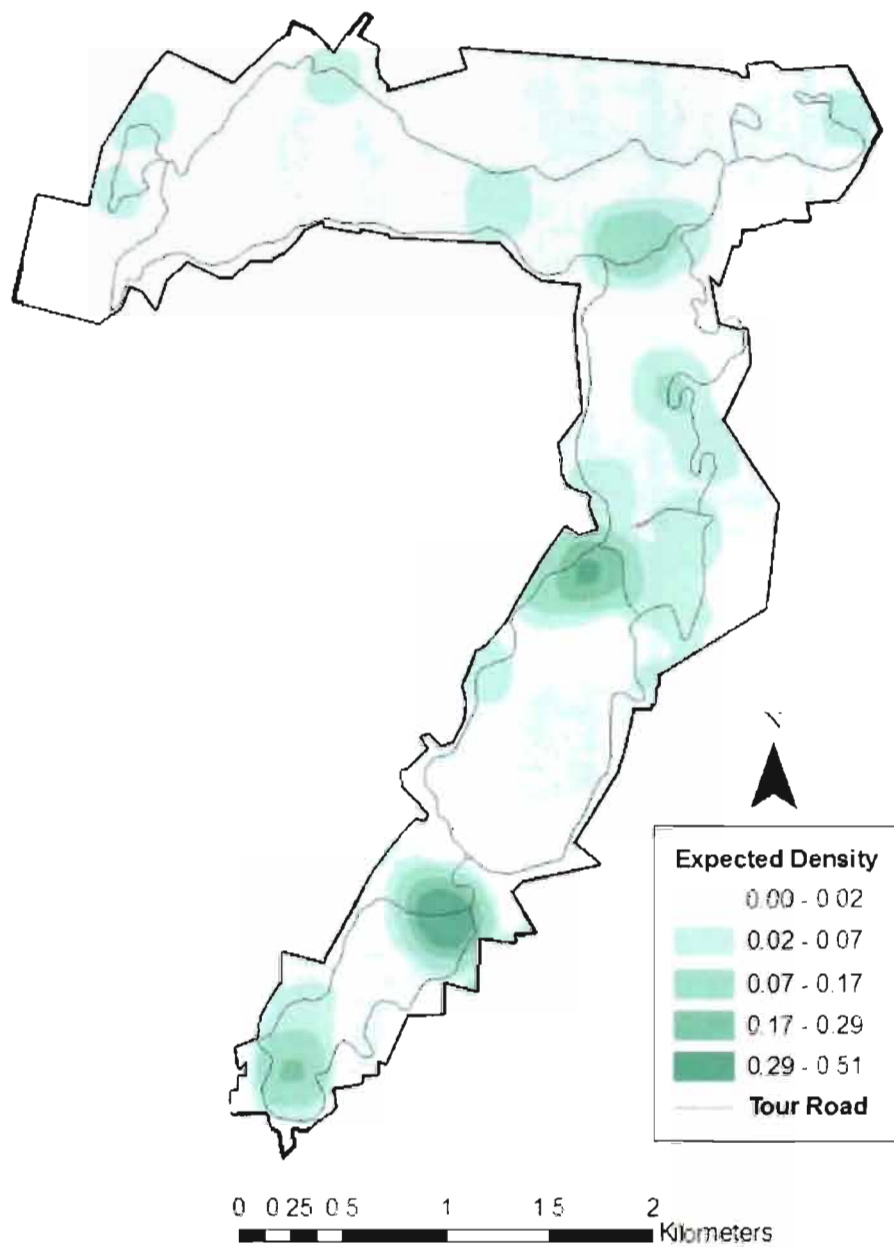


Figure 7. Expected deer densities across Vicksburg National Military Park for summer (26 September - 30 September) 2008.

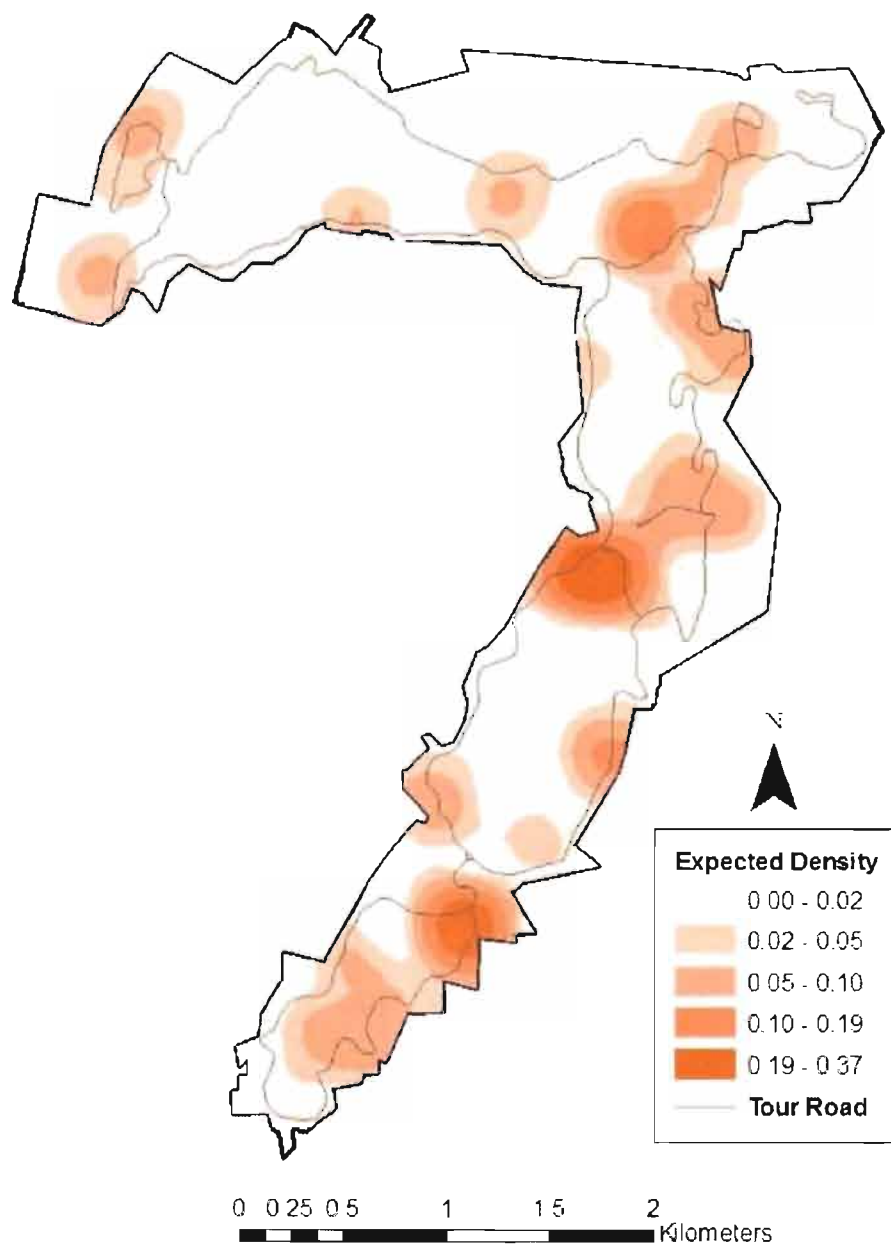


Figure 8. Expected deer densities across Vicksburg National Military Park for fall (11 December - 15 December) 2008.

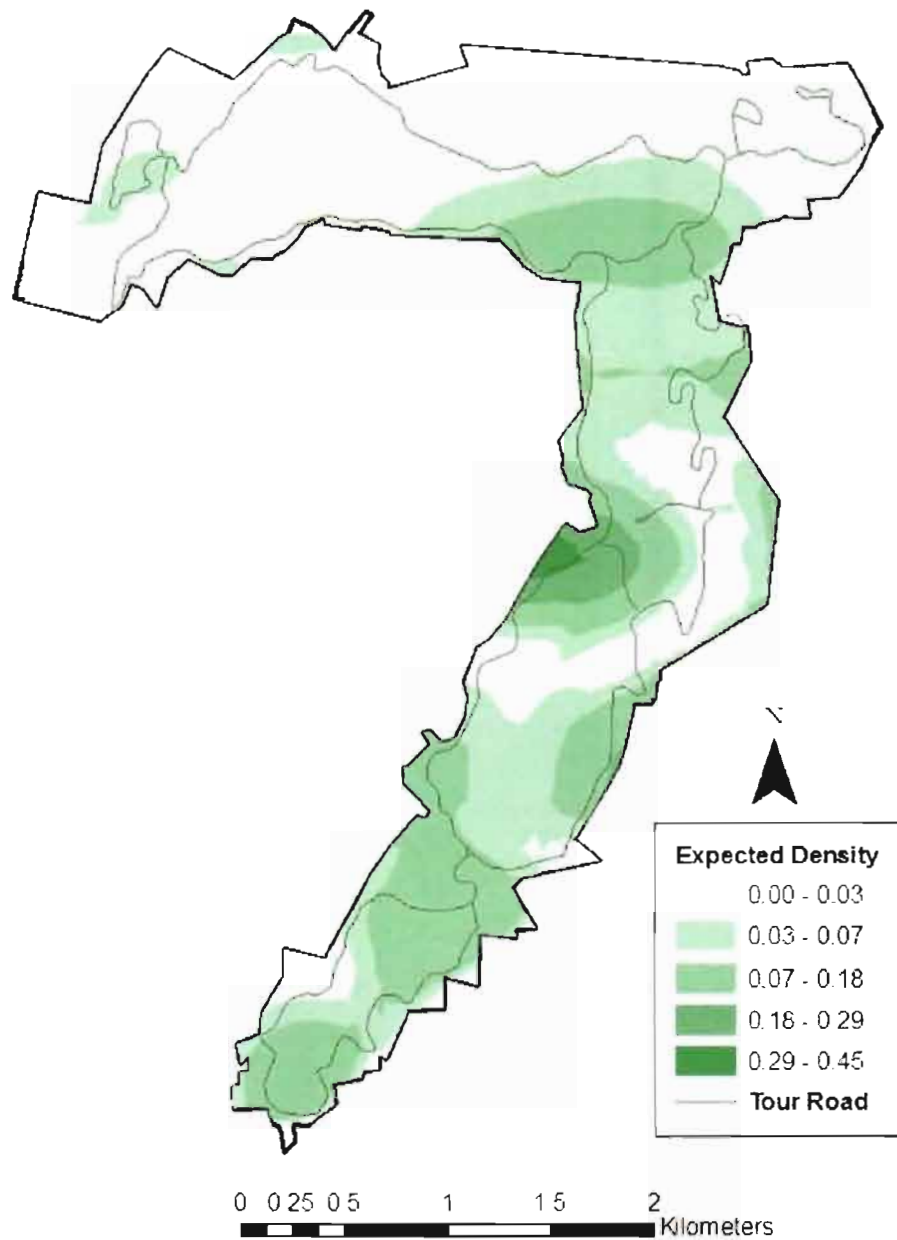


Figure 9. Expected deer densities across Vicksburg National Military Park for winter (3 March - 7 March) 2009.

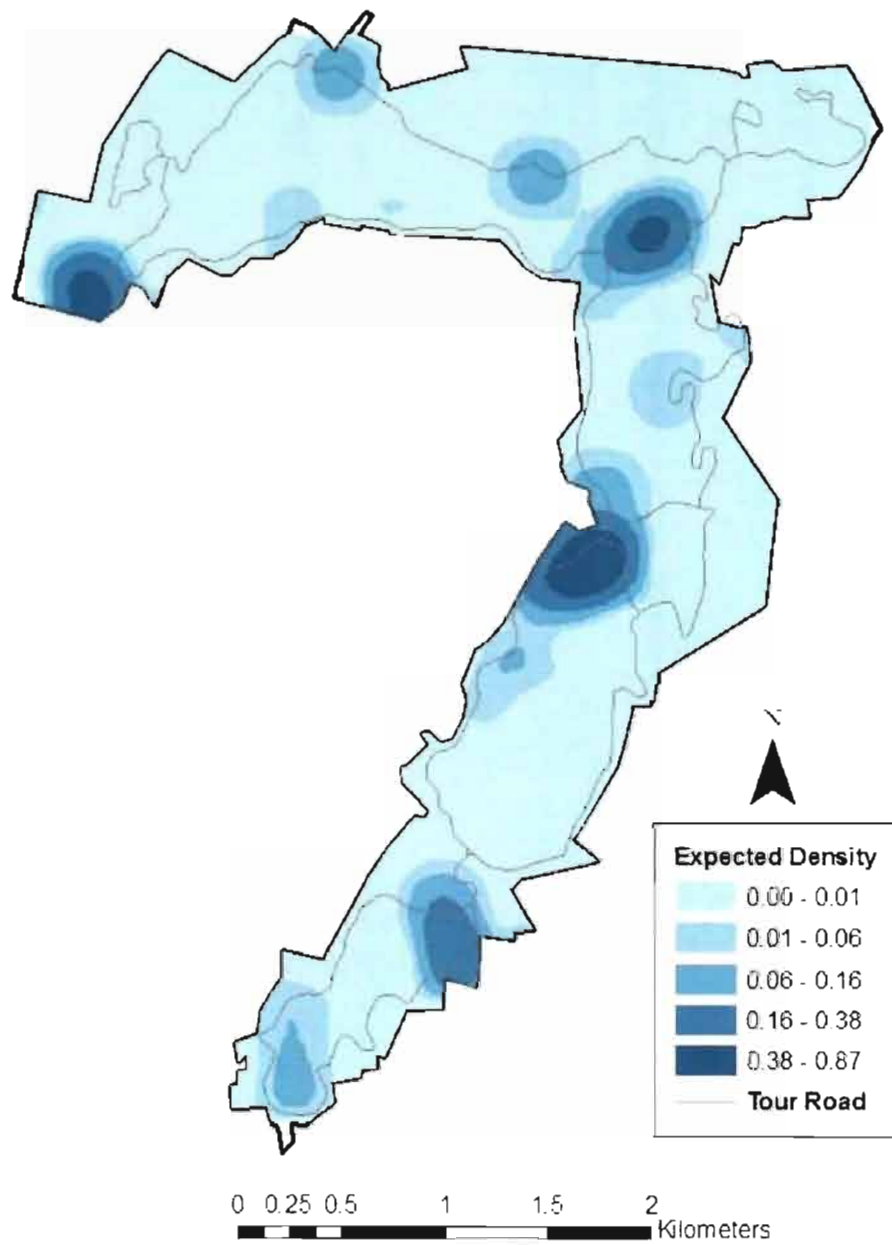


Figure 10. Expected deer densities across Vicksburg National Military Park for spring (12 May - 15 May 2009).

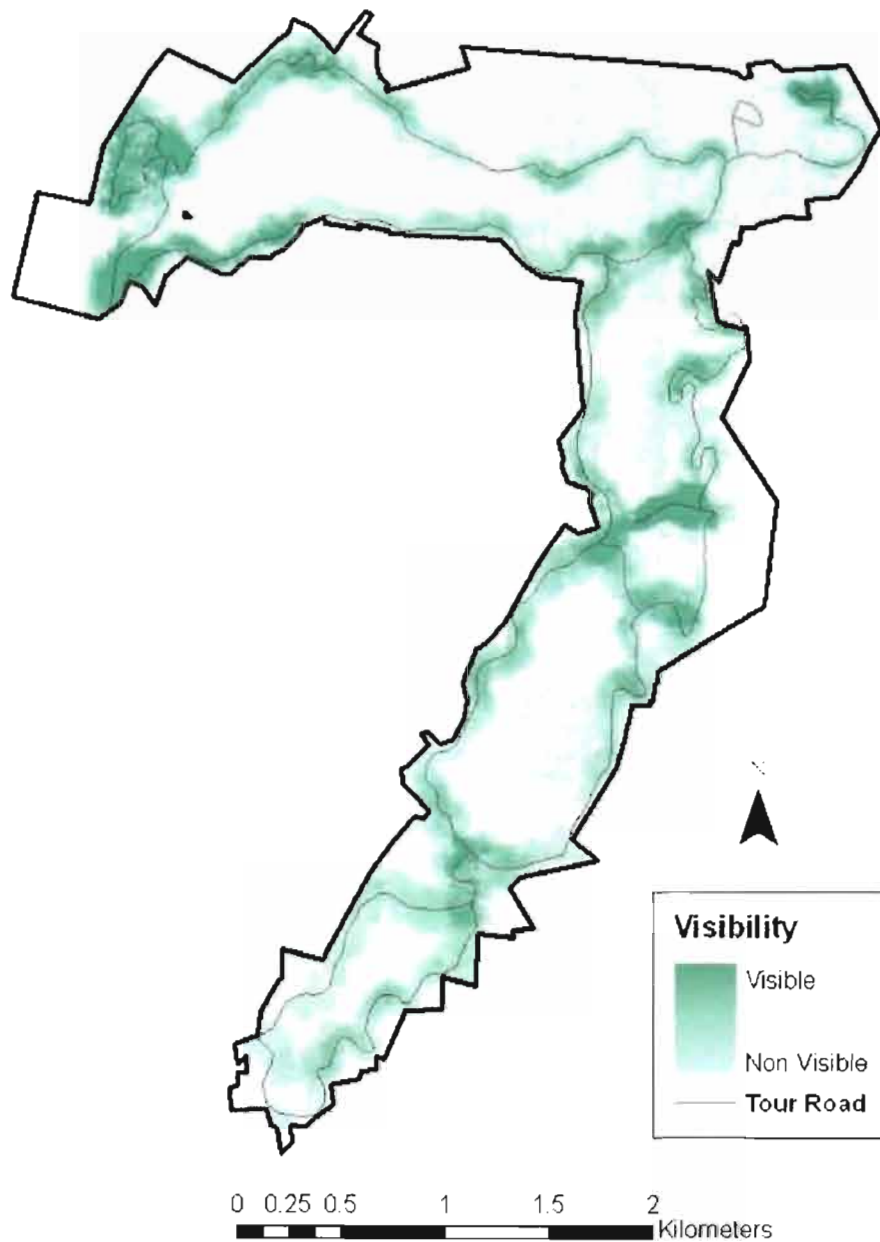


Figure 11. Visibility in summer (26 September - 30 September 2008) on Vicksburg National Military Park.

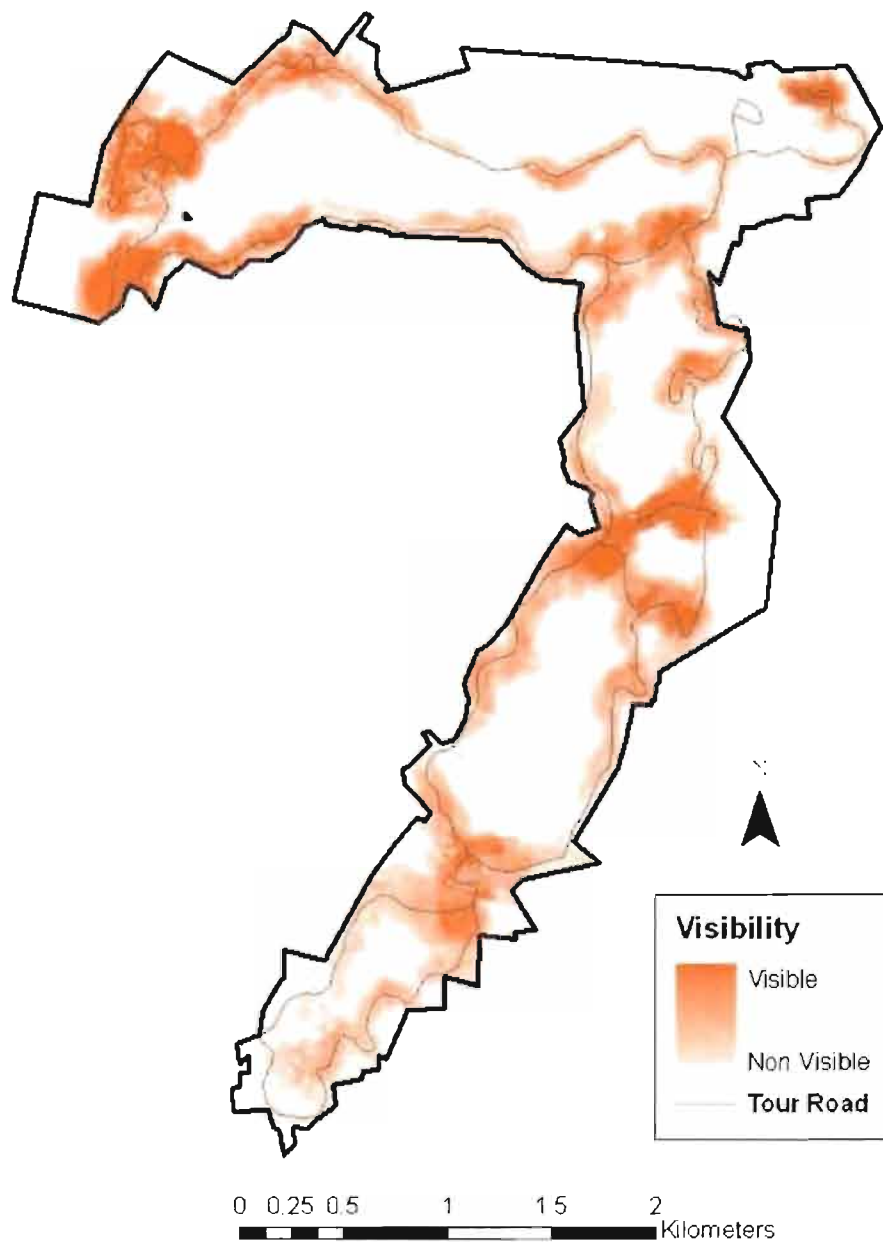


Figure 12. Visibility in fall (11 December - 15 December 2008) on Vicksburg National Military Park.

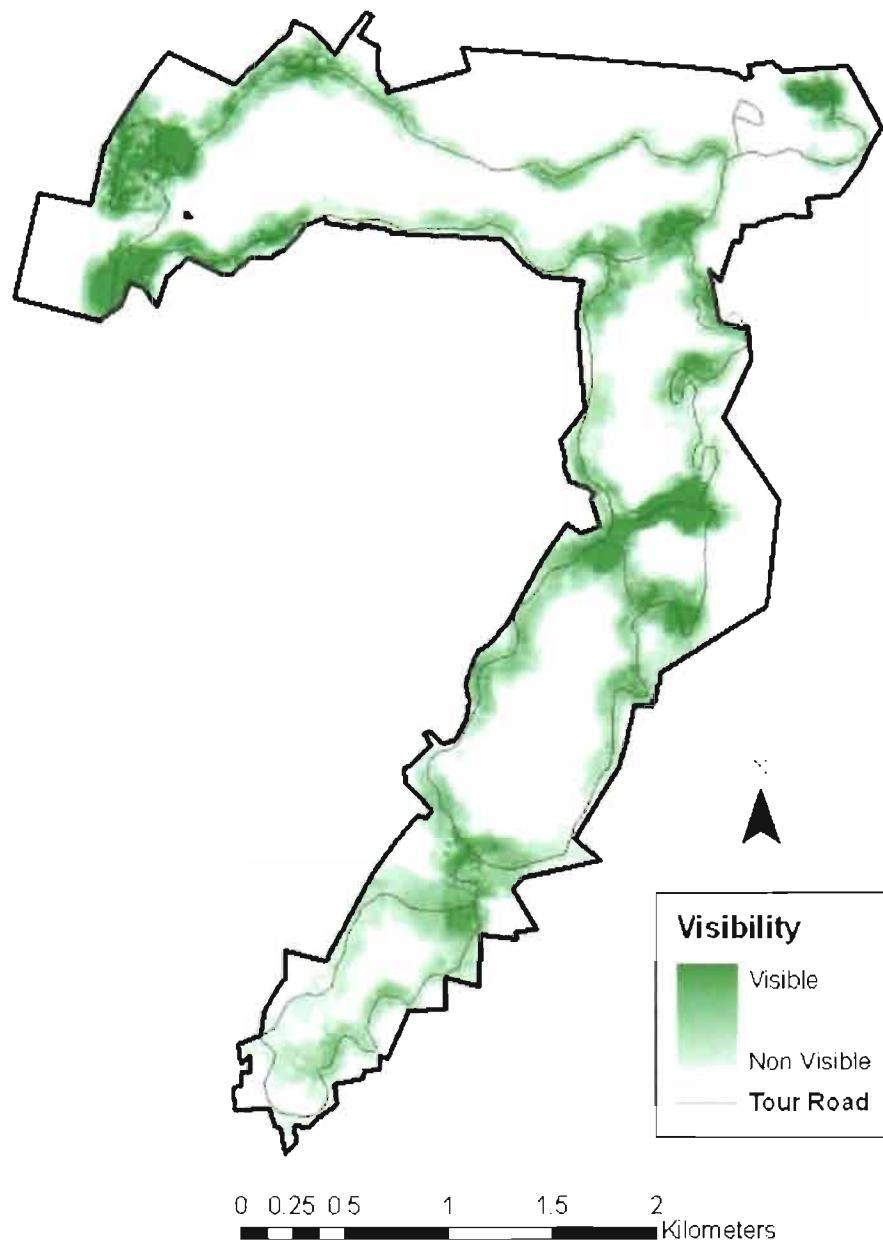


Figure 13. Visibility in winter (3 March - 7 March 2009) on Vicksburg National Military Park.

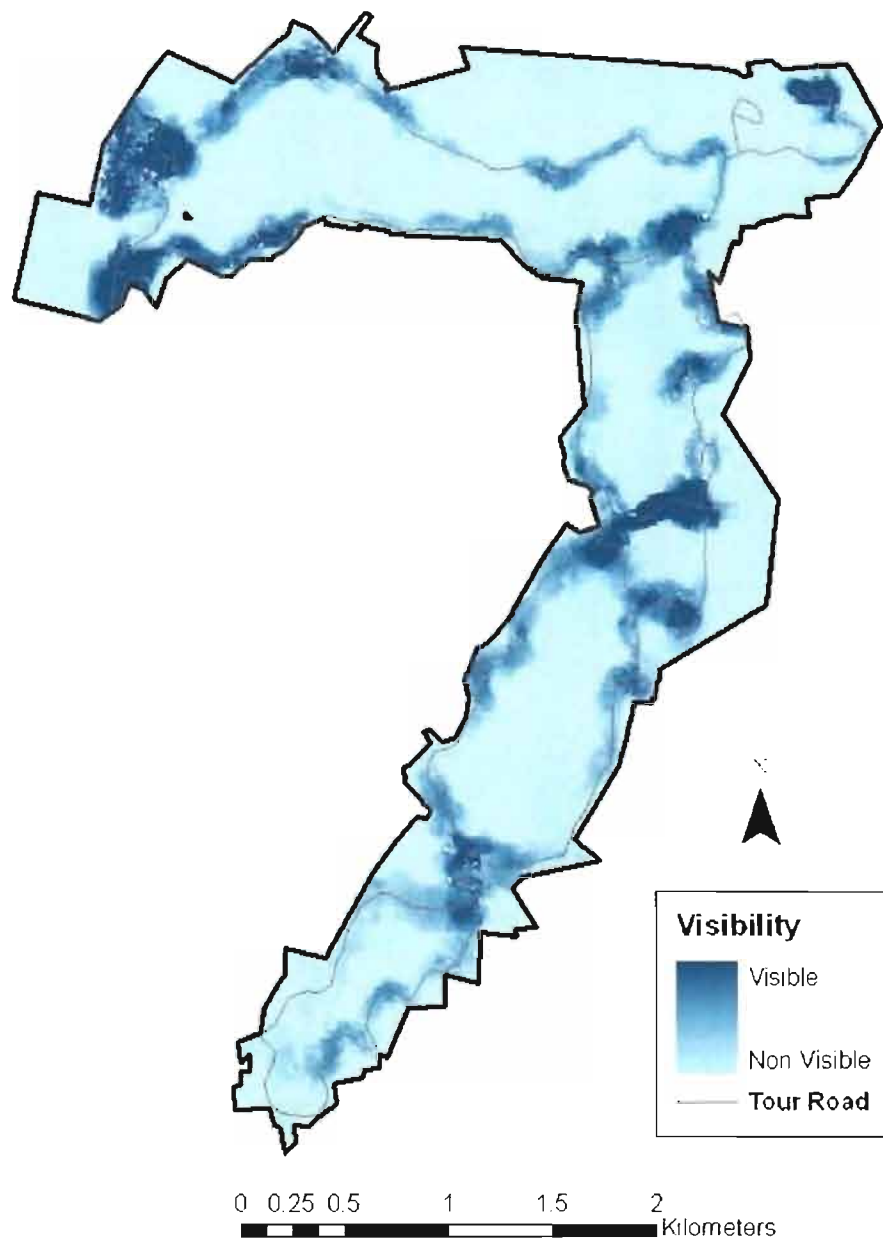


Figure 14. Visibility in spring (12 May - 15 May 2009) on Vicksburg National Military Park.

## CONCLUSIONS

We found deer densities likely to be near K within VICK across all seasons except winter, when densities likely exceed K. We found approximately a 3-fold increase in deer densities in winter compared to summer. We also observed a low number of fawns per 100 does that was indicative of a population near K. Even though the density and reproductive data indicated the population was near K, the vegetation was not impacted to the point of suggesting the population exceeded K (i.e., there were no observed browse lines).

We expect the selection of alternative C or D will result in an increase in deer density. The majority of the park is forested and conversion of forest to grasslands will increase the number of forest openings and therefore the amount of edge, the habitat of choice by white-tailed deer (Smith 1991). An increase in edge is expected to increase the carrying capacity of the VICK.

While we did not quantify forage in any cover type, our impression was that there was a low quantity of forage available under the canopy of most of the forest stands in the VICK. The forest stands may have provided cover and facilitated thermal regulation, but the edge and open fields were used more for foraging. As a result we also expect localized densities will increase under Alternatives C and D where forests are converted to grasslands.

Gorsira et al. (2006) indicated high densities (0.634 deer/ha) of white-tailed deer caused a decrease in plant diversity and seedling survival across three different habitat types in the Manassas National Battlefield Park (MNBK), Virginia. Density at MNBK was in excess of the expected carrying capacity by more than 4-fold. Density at VICK, by contrast, was thought to be near carrying capacity (0.056-0.125 deer/ha; Newsom 1984). VICK is about one third the size of MNBK and, as such, is not expected to respond in the same fashion if alternative C or D is implemented. Given the results of Gorsira et al. (2006), establishment of a vegetation monitoring effort is advised in light of the expected increase in deer density on VICK if alternative C or D is implemented.

## RECOMMENDATIONS

- 1) Continue to monitor population density at least annually and preferably seasonally. One year of seasonal data represents a snapshot in time and annual monitoring is required to detect trends and changes over time.
- 2) Stratify sampling for density estimation to account for different densities in different cover types if resources allow. This will require more effort, but will yield an estimate of better precision.
- 3) Continue to monitor reproduction annually. This vital statistic is required to fully understand the population dynamics over time and to be able to predict the population trajectory given density.
- 4) Establish a vegetation monitoring program in selected habitat types. Deer have the capacity to alter the community composition and structure of vegetation. Monitoring how vegetation responds to changing deer densities will aid in future management efforts of deer and vegetation.

- 5) Establish the relationship between population size and reproductive (i.e., recruitment) data. The data presented in this work represent one data point in time. Knowing this relationship will also aid in future deer management efforts.
- 6) Estimate or index mortality. This vital statistic is expected to be negligible for deer occupying VICK. Seasonal densities, especially winter, will likely be affected by mortality occurring outside the VICK boundary. The deer population is not contained within the boundary of the property and is likely affected by the mortality due to harvest that occurs outside the boundary. This information will likely help to understand winter densities and change over time as the human population grows.

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## APPENDIX

Table A1. Number of deer observed per night by sex and age from 26-30 September 2008 on the Vicksburg National Military Park.

| Night   | # of groups | Bucks | Does | Fawns | Unknown | Total |
|---------|-------------|-------|------|-------|---------|-------|
| 26 Sept | 12          | 1     | 14   | 3     | 7       | 25    |
| 27 Sept | 16          | 8     | 28   | 0     | 0       | 36    |
| 28 Sept | 11          | 5     | 15   | 1     | 4       | 25    |
| 29 Sept | 15          | 4     | 9    | 1     | 8       | 22    |
| 30 Sept | 15          | 8     | 13   | 1     | 6       | 28    |
| Total   | 69          | 26    | 79   | 6     | 25      | 136   |
| Mean    | 13.8        | 5.2   | 15.8 | 1.2   | 5       |       |

Table A2. Number of deer observed per night by sex and age from 11-15 December 2008 on the Vicksburg National Military Park.

| Night  | # of groups | Bucks | Does | Fawns | Unknown | Total |
|--------|-------------|-------|------|-------|---------|-------|
| 11 Dec | 12          | 6     | 4    | 1     | 11      | 22    |
| 12 Dec | 21          | 9     | 17   | 5     | 11      | 42    |
| 13 Dec | 15          | 10    | 8    | 5     | 4       | 27    |
| 14 Dec | 19          | 9     | 23   | 3     | 8       | 43    |
| 15 Dec | 8           | 4     | 7    | 4     | 1       | 16    |
| Total  | 75          | 38    | 59   | 18    | 35      | 150   |
| Mean   | 15.0        | 7.6   | 11.8 | 3.6   | 7       |       |

Table A3. Number of deer observed per night by sex and age from 3-7 March 2009 on the Vicksburg National Military Park.

| Night   | # of groups | Bucks | Does | Fawns | Unknown | Total |
|---------|-------------|-------|------|-------|---------|-------|
| 3 March | 21          | 6     | 19   | 9     | 37      | 71    |
| 4 March | 22          | 8     | 17   | 7     | 34      | 66    |
| 5 March | 16          | 7     | 32   | 12    | 14      | 65    |
| 6 March | 16          | 1     | 20   | 14    | 24      | 59    |
| 7 March | 11          | 3     | 14   | 3     | 19      | 39    |
| Total   | 86          | 25    | 102  | 45    | 128     | 300   |
| Mean    | 17.2        | 5.0   | 20.4 | 9.0   | 25.6    |       |

Table A4. Number of deer observed per night by sex and age from 12-15 May 2009 on the Vicksburg National Military Park.

| Night  | # of groups | Bucks | Does | Fawns | Unknown | Total |
|--------|-------------|-------|------|-------|---------|-------|
| 12 May | 14          | 0     | 6    | 4     | 30      | 40    |
| 13 May | 12          | 0     | 2    | 0     | 30      | 32    |
| 14 May | 15          | 0     | 0    | 0     | 45      | 45    |
| 15 May | 14          | 1     | 0    | 0     | 54      | 55    |
| Total  | 55          | 1     | 8    | 4     | 159     | 172   |
| Mean   | 13.75       | 0.25  | 2    | 1     | 39.75   |       |

Table A5. Number of groups of white-tailed deer by sex and age per area from 26-30 September 2008 on Vicksburg National Military Park.

| <b>Area</b>   | <b># of groups</b> | <b>Bucks</b> | <b>Does</b> | <b>Fawns</b> | <b>Unknown</b> | <b>Total</b> |
|---------------|--------------------|--------------|-------------|--------------|----------------|--------------|
| Northern      | 14                 | 6            | 12          | 0            | 6              | 24           |
| North-central | 17                 | 5            | 9           | 1            | 7              | 22           |
| South-central | 18                 | 11           | 15          | 3            | 4              | 33           |
| South         | 20                 | 4            | 43          | 2            | 8              | 57           |
| Total         | 69                 | 26           | 79          | 6            | 25             | 136          |
| Mean          | 17.25              | 6.50         | 19.75       | 1.50         | 6.25           |              |

Table A6. Number of groups of white-tailed deer by sex and age per area from 11-15 December 2008 on Vicksburg National Military Park.

| <b>Area</b>   | <b># of groups</b> | <b>Bucks</b> | <b>Does</b> | <b>Fawns</b> | <b>Unknown</b> | <b>Total</b> |
|---------------|--------------------|--------------|-------------|--------------|----------------|--------------|
| Northern      | 21                 | 15           | 18          | 2            | 3              | 38           |
| North-central | 19                 | 7            | 11          | 3            | 12             | 33           |
| South-central | 16                 | 4            | 16          | 12           | 7              | 39           |
| South         | 19                 | 12           | 14          | 1            | 13             | 40           |
| Total         | 75                 | 38           | 59          | 18           | 35             | 150          |
| Mean          | 18.75              | 9.50         | 14.75       | 4.50         | 8.75           |              |

Table A7. Number of groups of white-tailed deer by sex and age per area from 3-7 March 2009 on Vicksburg National Military Park.

| <b>Area</b>   | <b># of groups</b> | <b>Bucks</b> | <b>Does</b> | <b>Fawns</b> | <b>Unknown</b> | <b>Total</b> |
|---------------|--------------------|--------------|-------------|--------------|----------------|--------------|
| Northern      | 23                 | 6            | 14          | 8            | 39             | 67           |
| North-central | 23                 | 2            | 22          | 17           | 16             | 57           |
| South-central | 24                 | 5            | 32          | 16           | 54             | 107          |
| South         | 16                 | 12           | 34          | 4            | 19             | 69           |
| Total         | 86                 | 25           | 102         | 45           | 128            | 300          |
| Mean          | 21.50              | 6.25         | 25.50       | 11.25        | 32.00          |              |

Table A8. Number of groups of white-tailed deer by sex and age per area from 12-15 May 2009 on Vicksburg National Military Park.

| <b>Area</b>   | <b># of groups</b> | <b>Bucks</b> | <b>Does</b> | <b>Fawns</b> | <b>Unknown</b> | <b>Total</b> |
|---------------|--------------------|--------------|-------------|--------------|----------------|--------------|
| Northern      | 23                 | 1            | 3           | 0            | 63             | 67           |
| North-central | 9                  | 0            | 0           | 0            | 16             | 16           |
| South-central | 13                 | 0            | 2           | 2            | 54             | 58           |
| South         | 10                 | 0            | 3           | 2            | 26             | 31           |
| Total         | 55                 | 1            | 8           | 4            | 159            | 172          |
| Mean          | 13.75              | 0.25         | 2.00        | 1.00         | 39.75          |              |

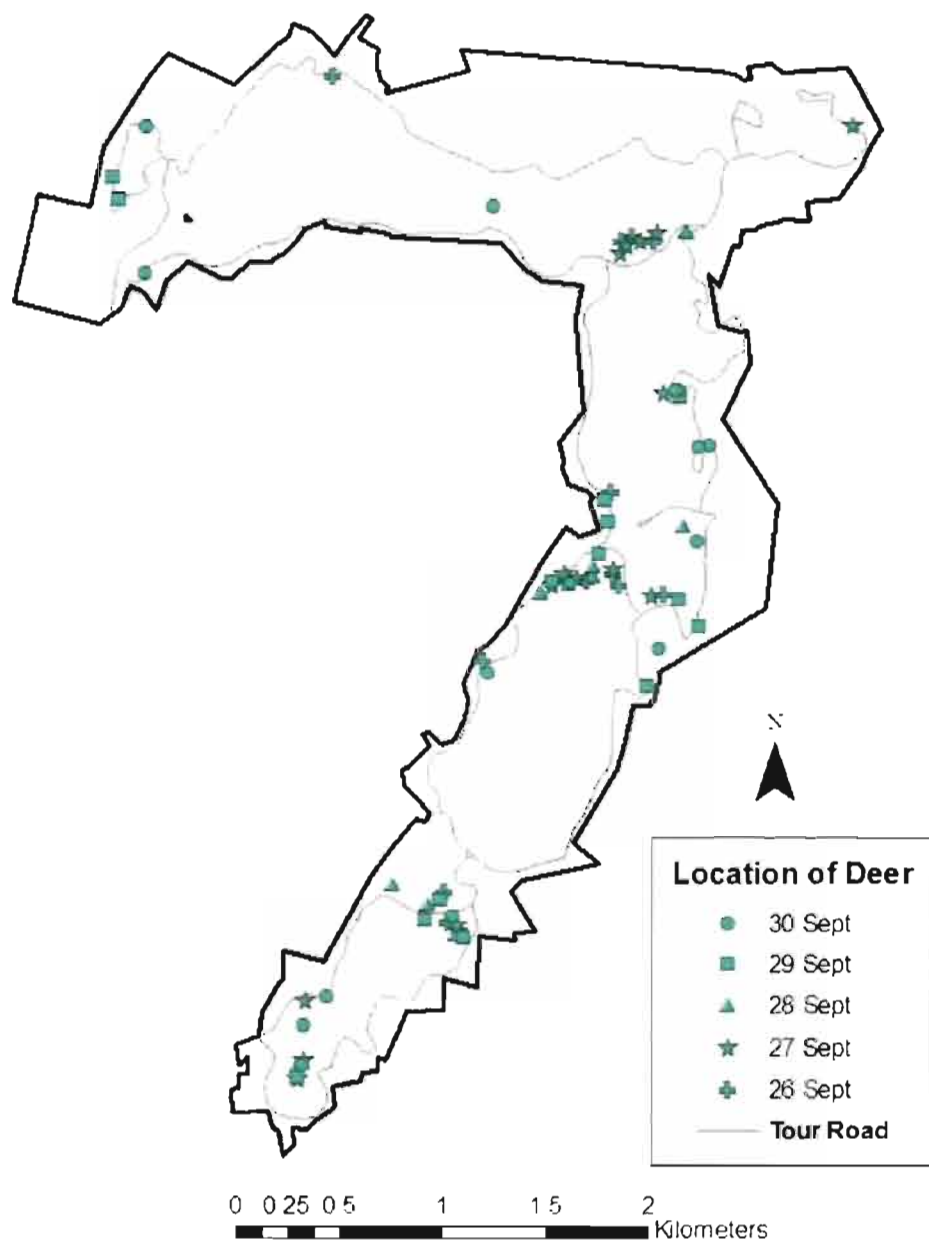


Figure A1. Locations of deer on Vicksburg National Military Park, 26 September – 30 September 2008.

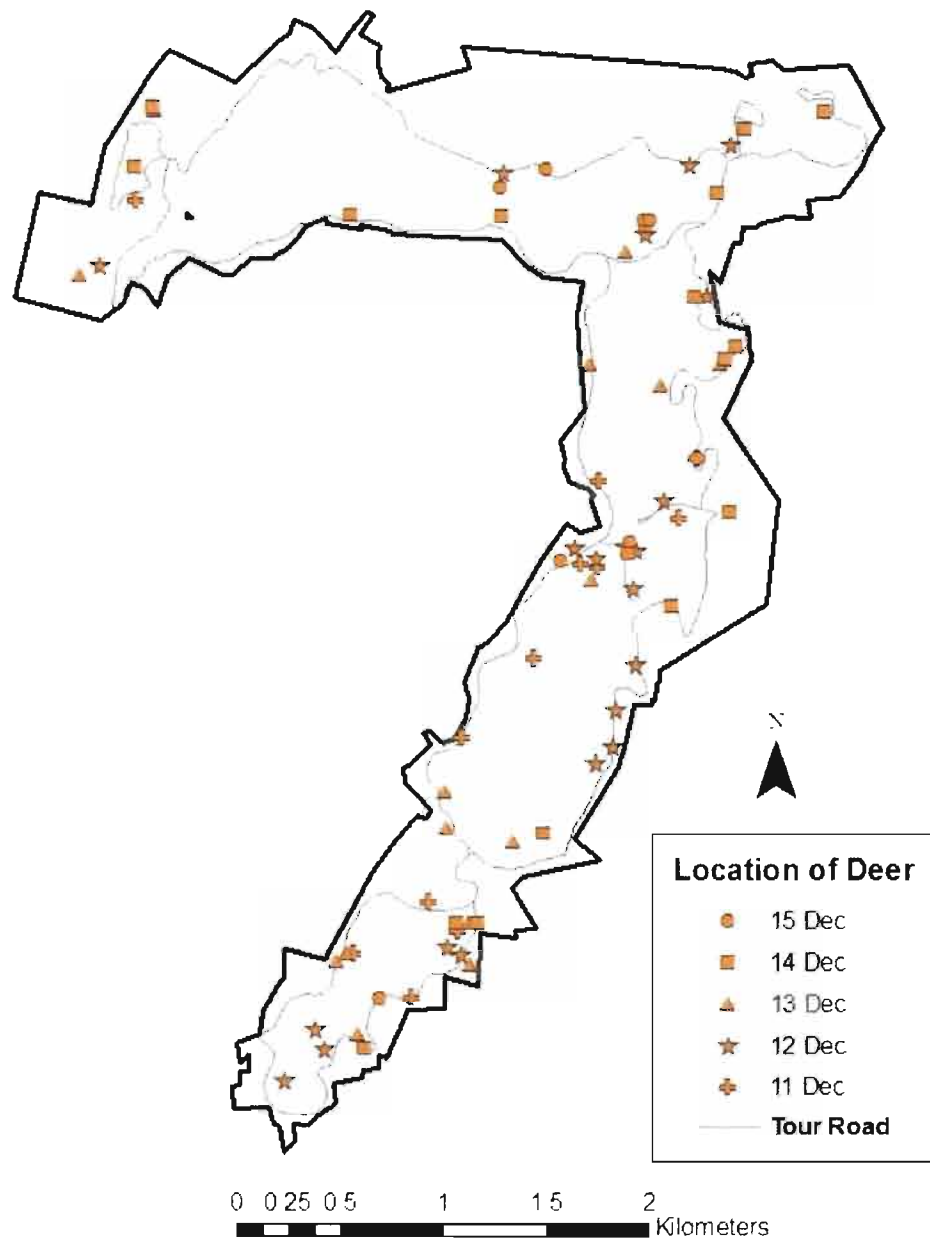


Figure A2. Locations of deer on Vicksburg National Military Park, 11 December – 15 December 2008.

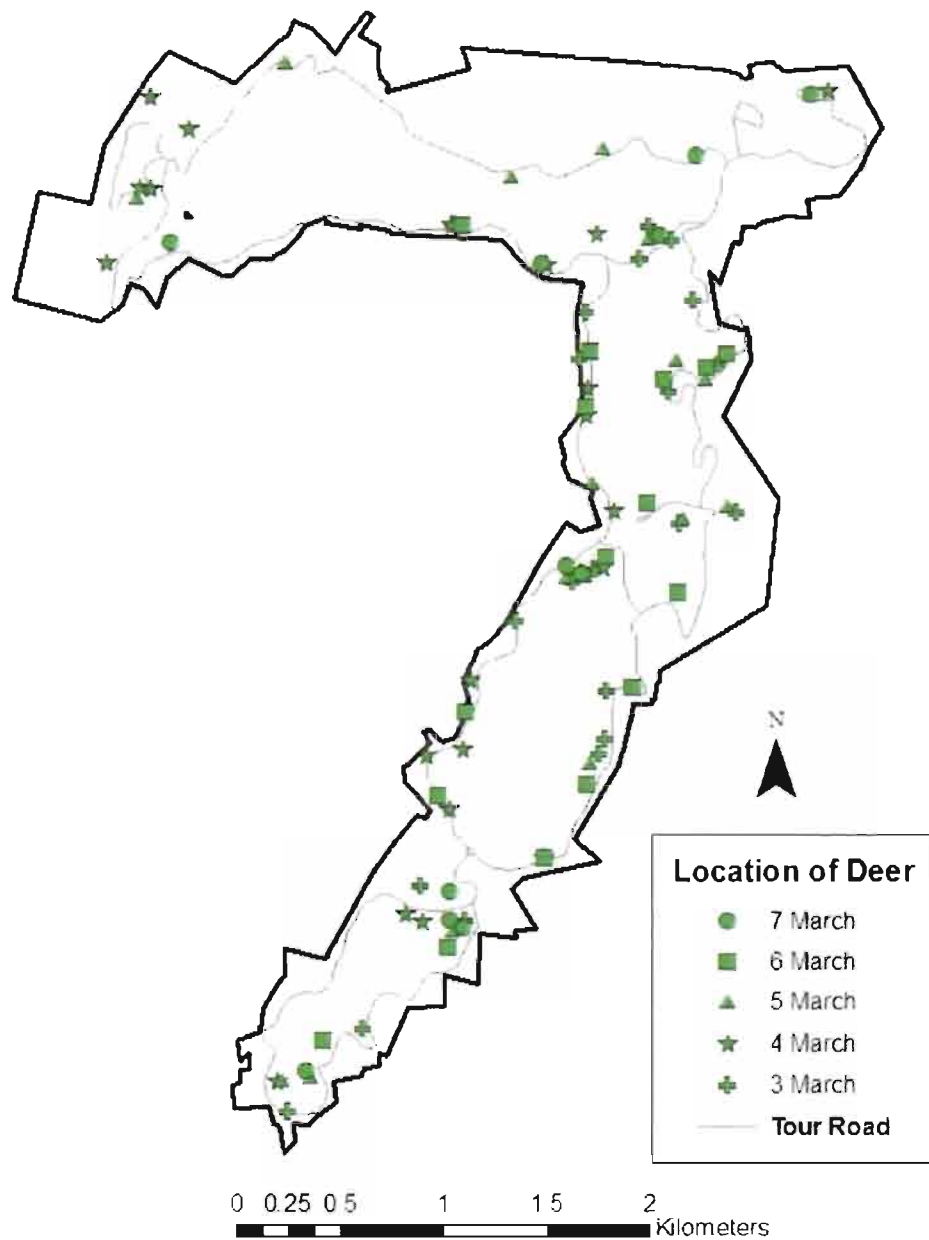


Figure A3. Locations of deer on Vicksburg National Military Park, 3 March – 7 March 2009.

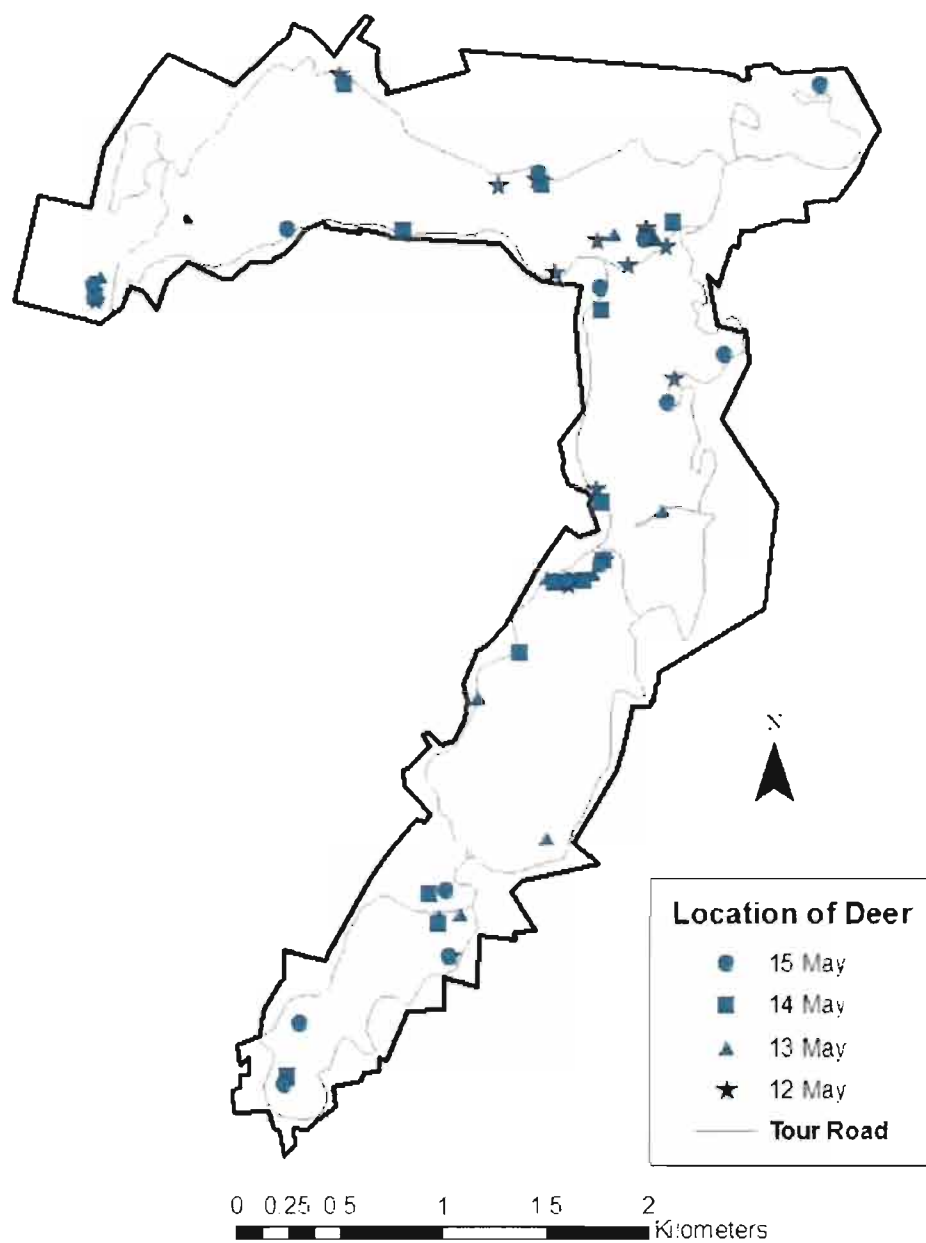


Figure A4. Locations of deer on Vicksburg National Military Park, 12 May – 15 May 2009.

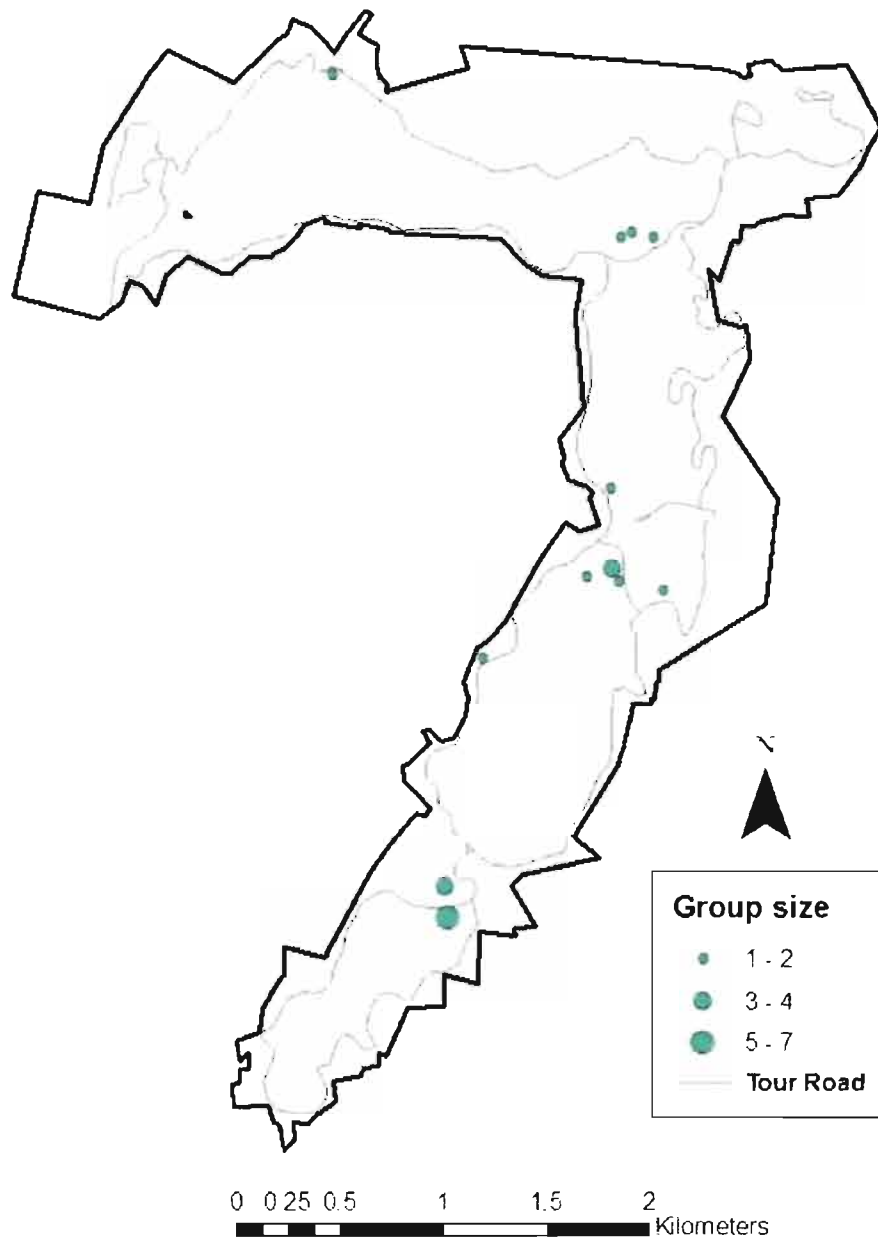


Figure A5. Locations of deer on Vicksburg National Military Park, 26 September 2008.

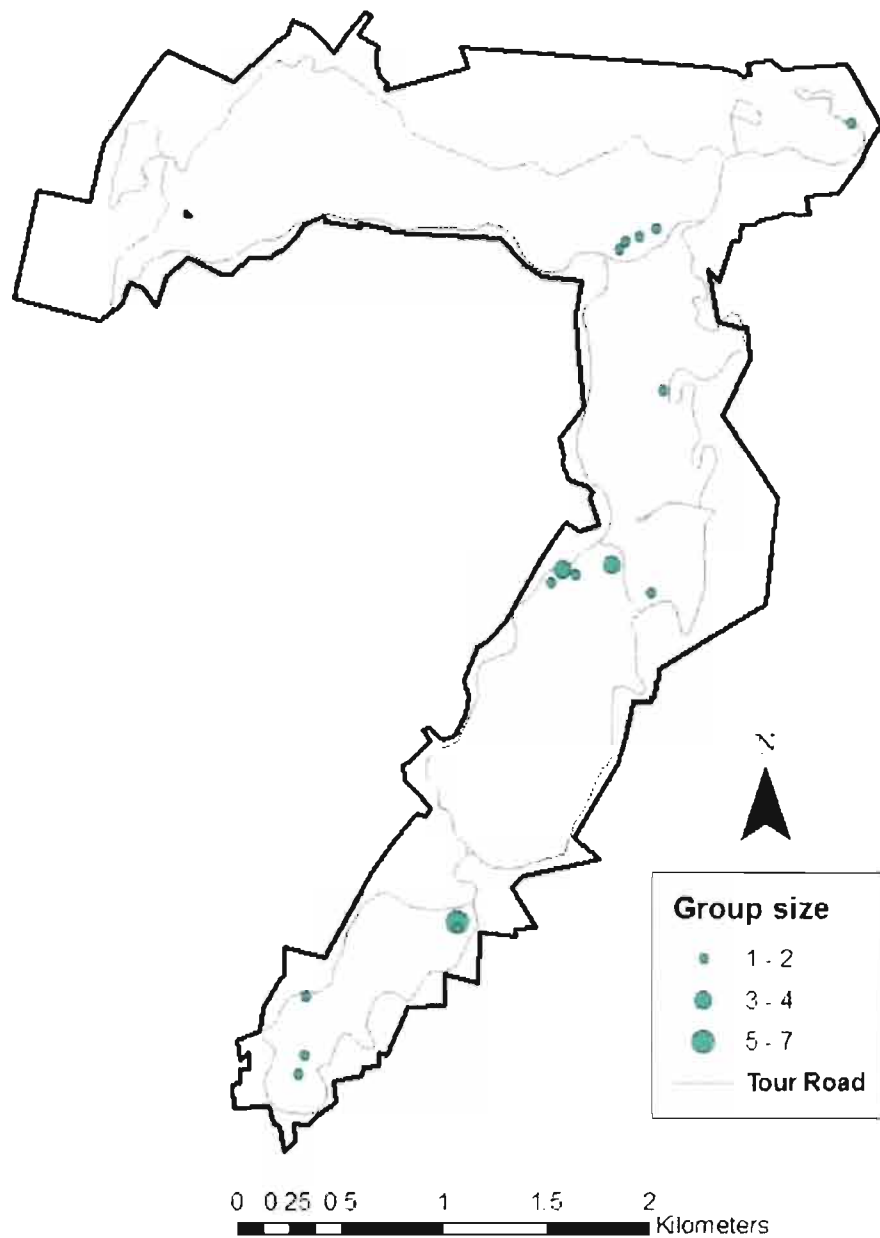


Figure A6. Locations of deer on Vicksburg National Military Park, 27 September 2008.

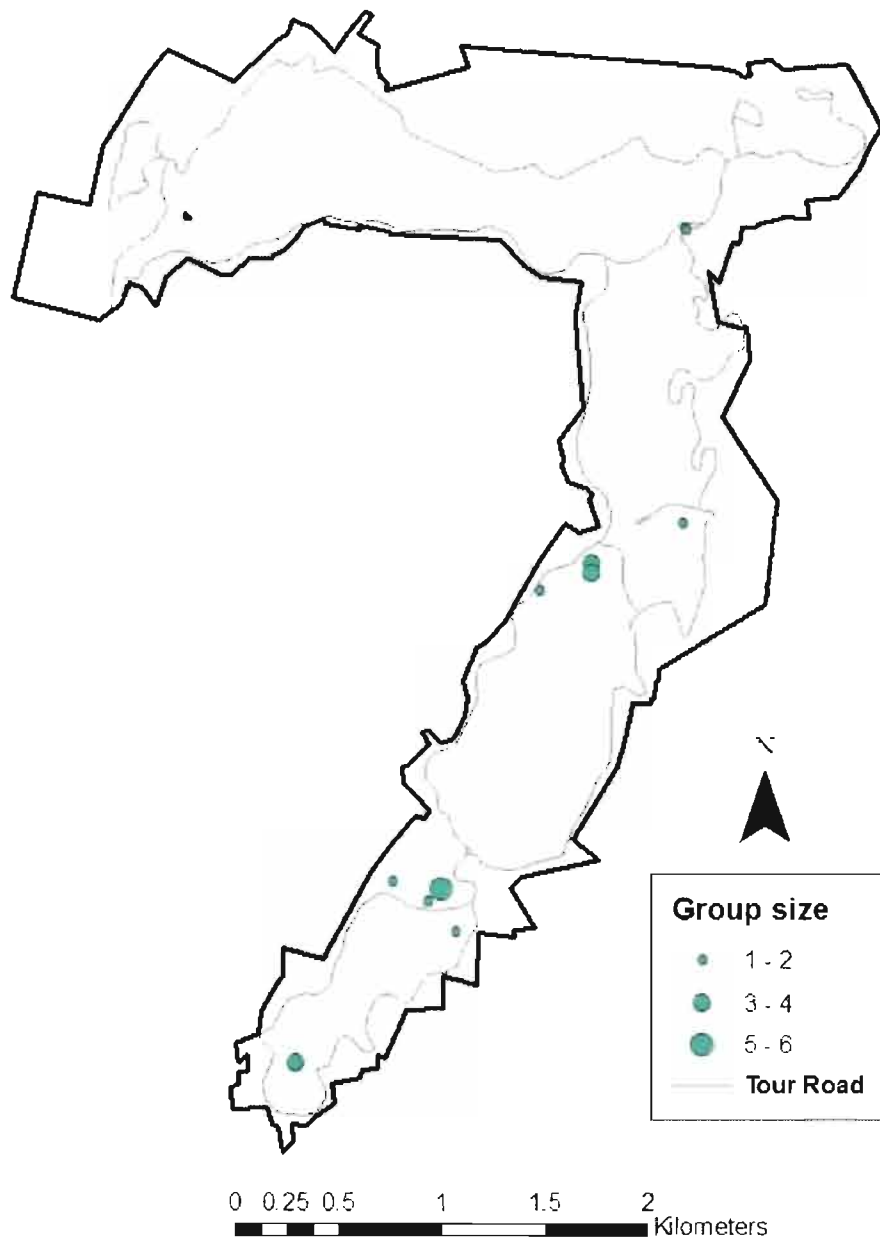


Figure A7. Locations of deer on Vicksburg National Military Park, 28 September 2008.

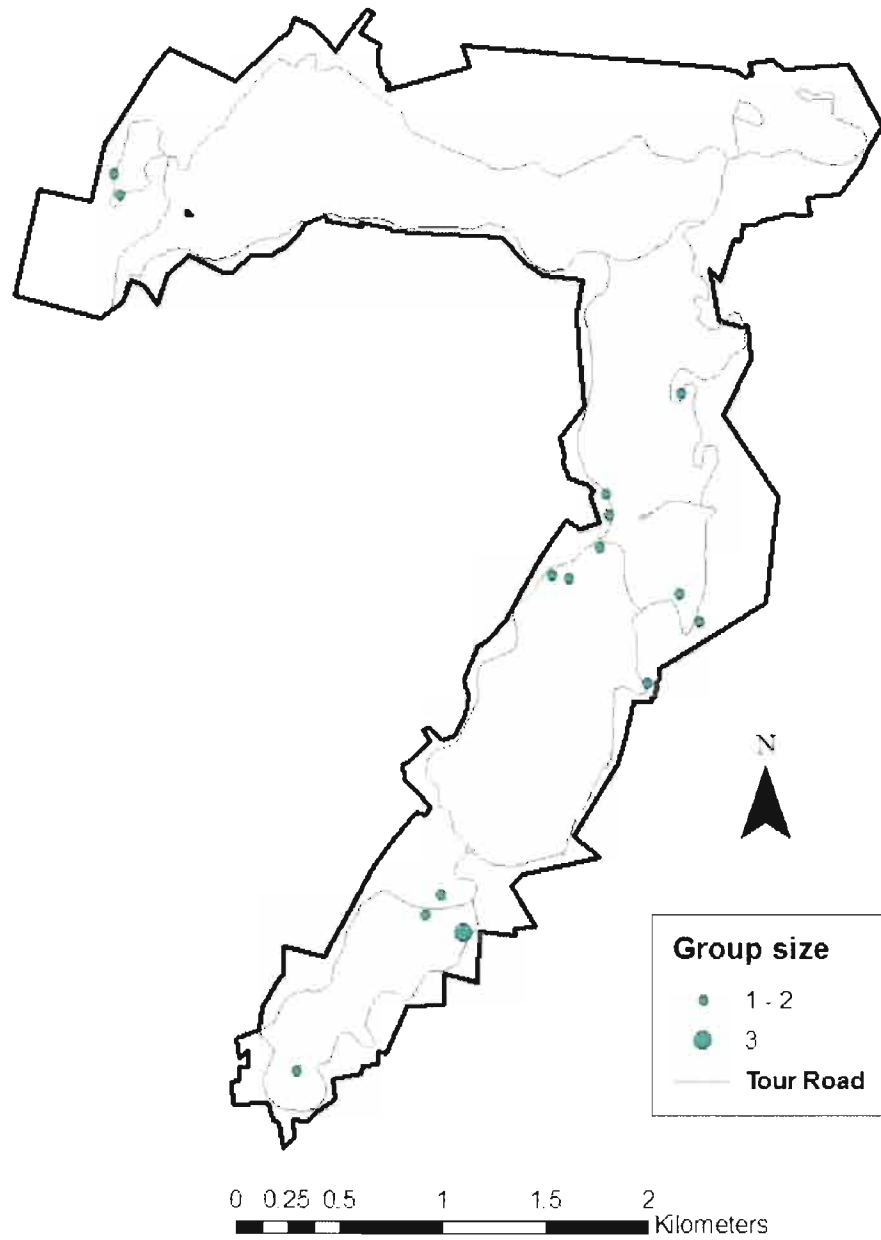


Figure A8. Locations of deer on Vicksburg National Military Park, 29 September 2008.

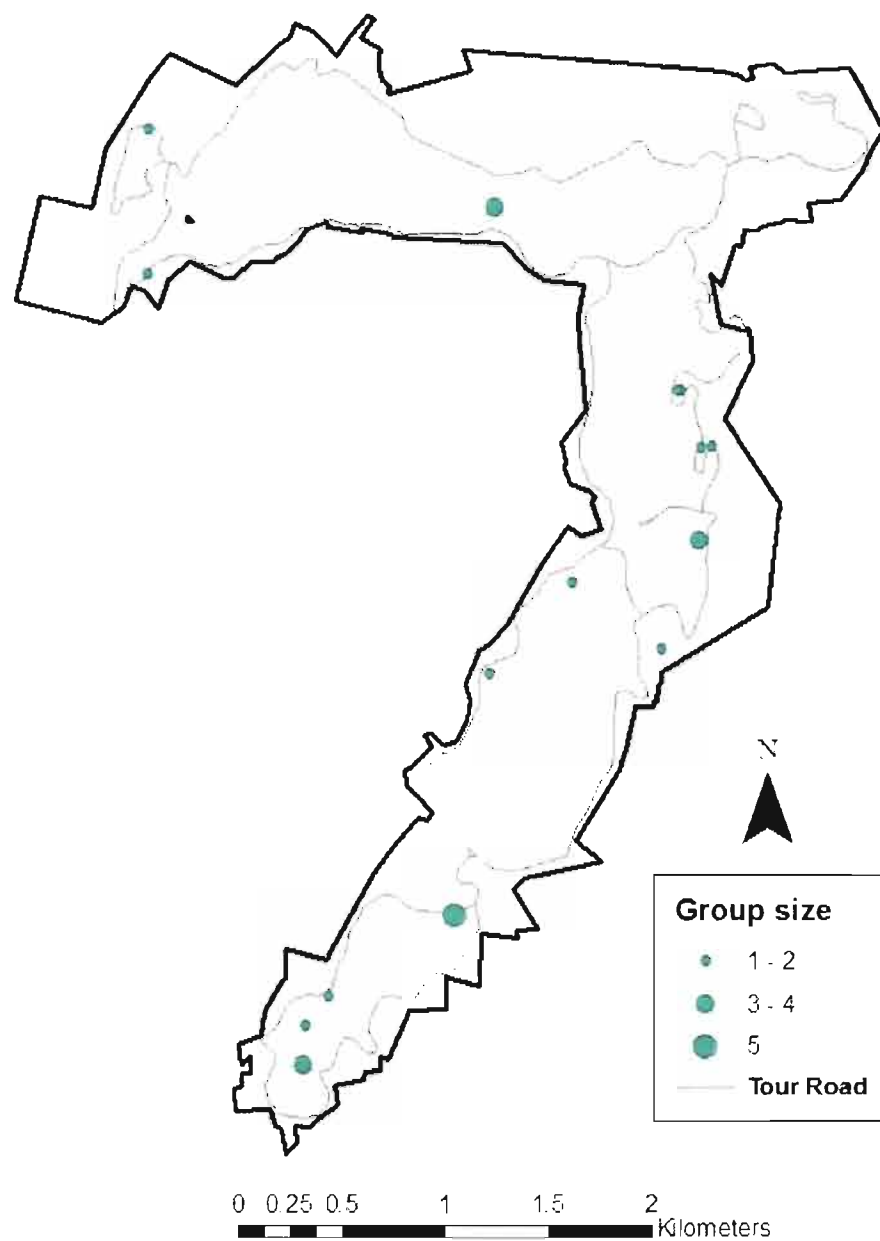


Figure A9. Locations of deer on Vicksburg National Military Park, 30 September 2008.

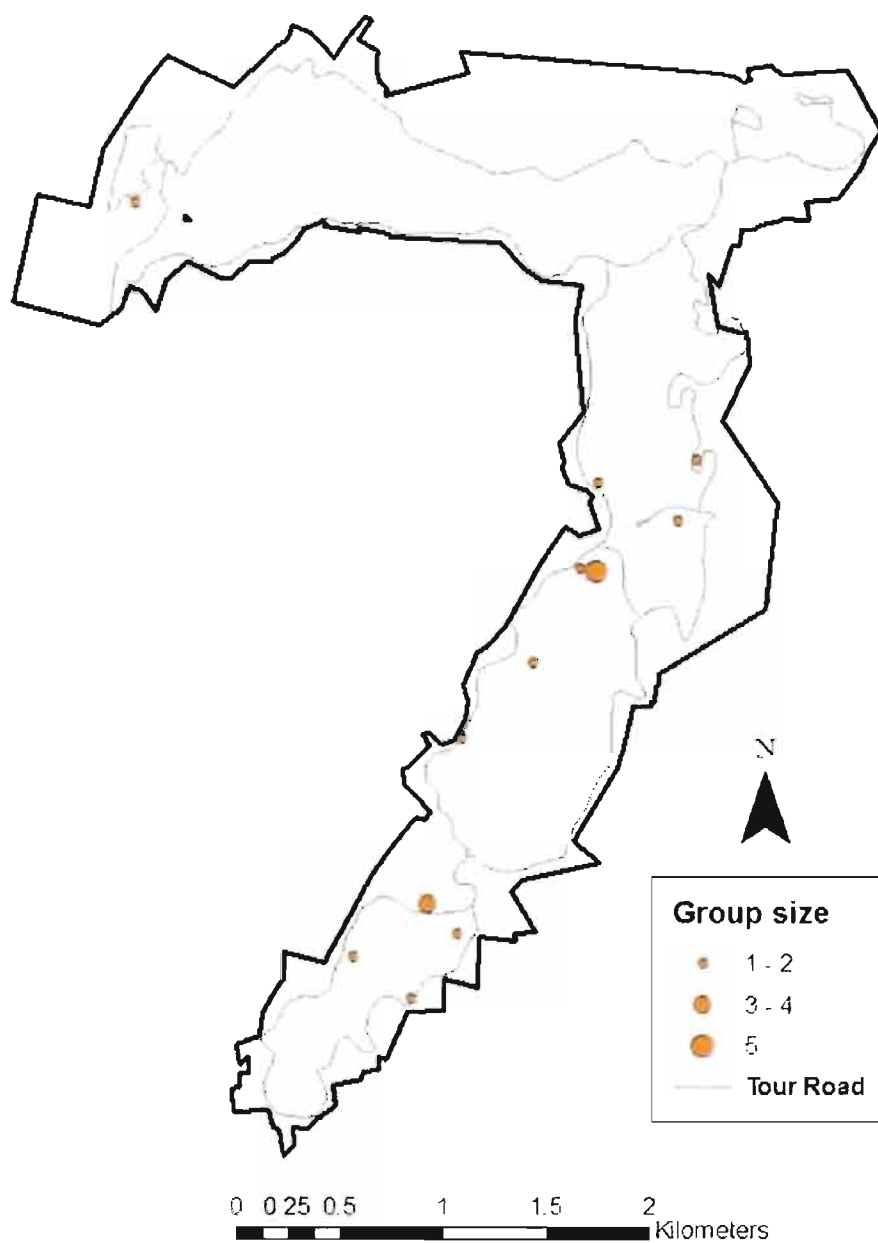


Figure A10. Locations of deer on Vicksburg National Military Park, 11 December 2008.

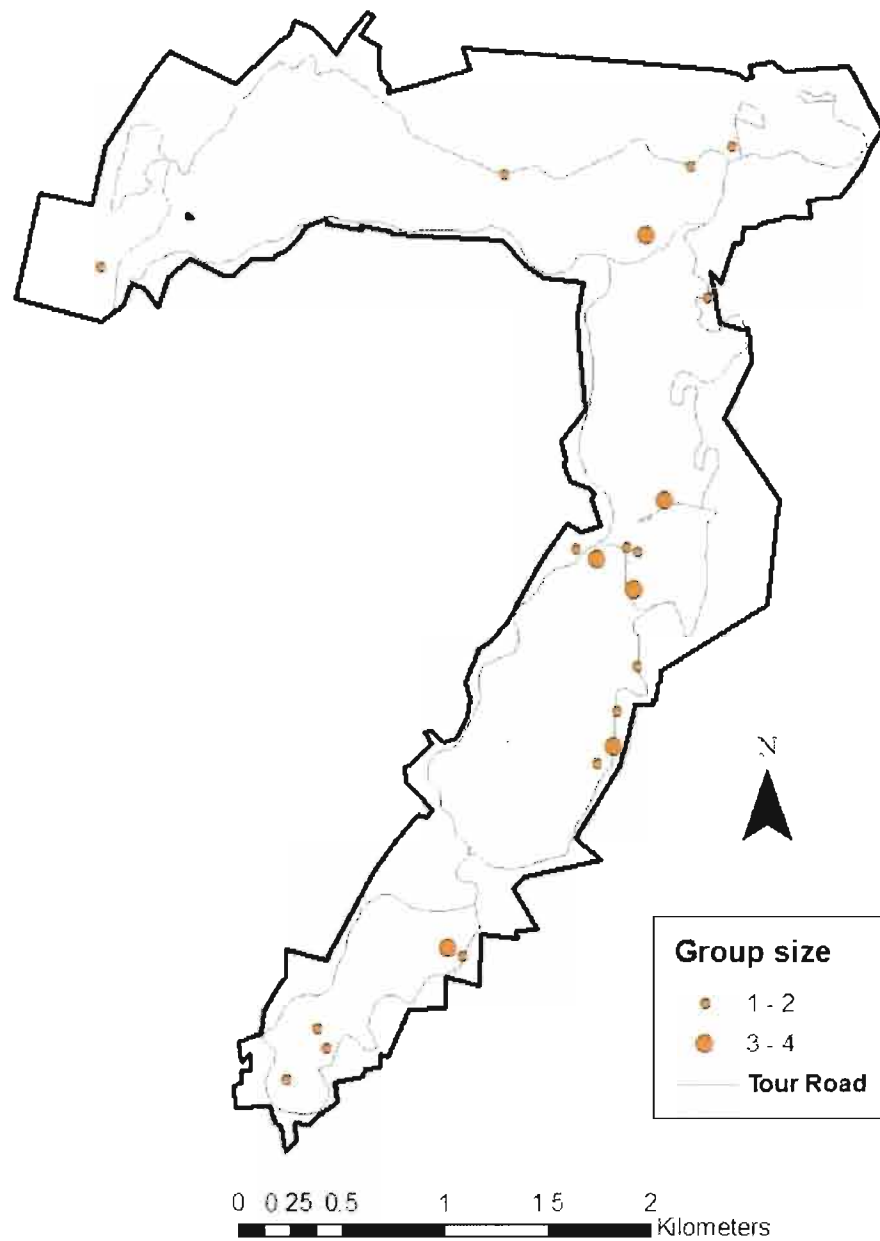


Figure A11. Locations of deer on Vicksburg National Military Park, 12 December 2008.

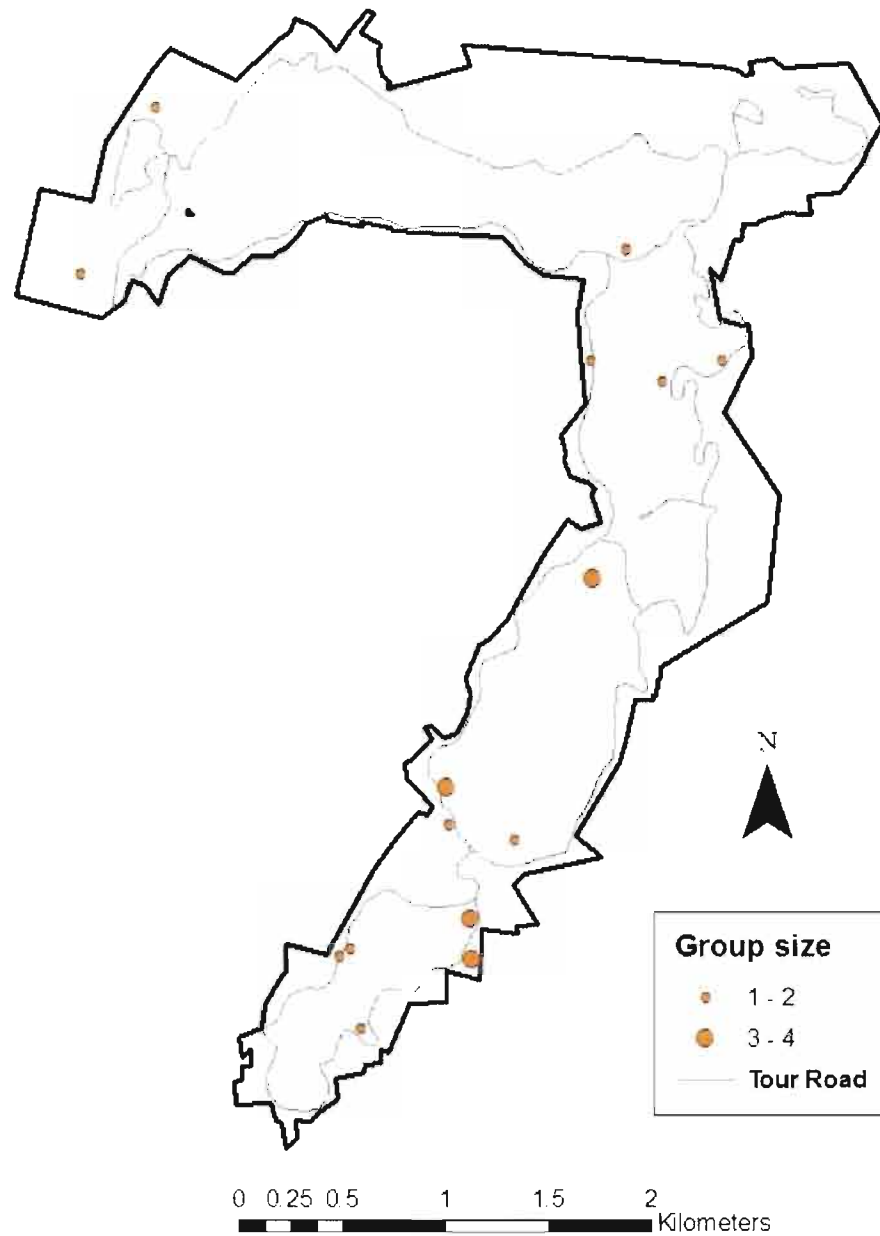


Figure A12. Locations of deer on Vicksburg National Military Park, 13 December 2008.

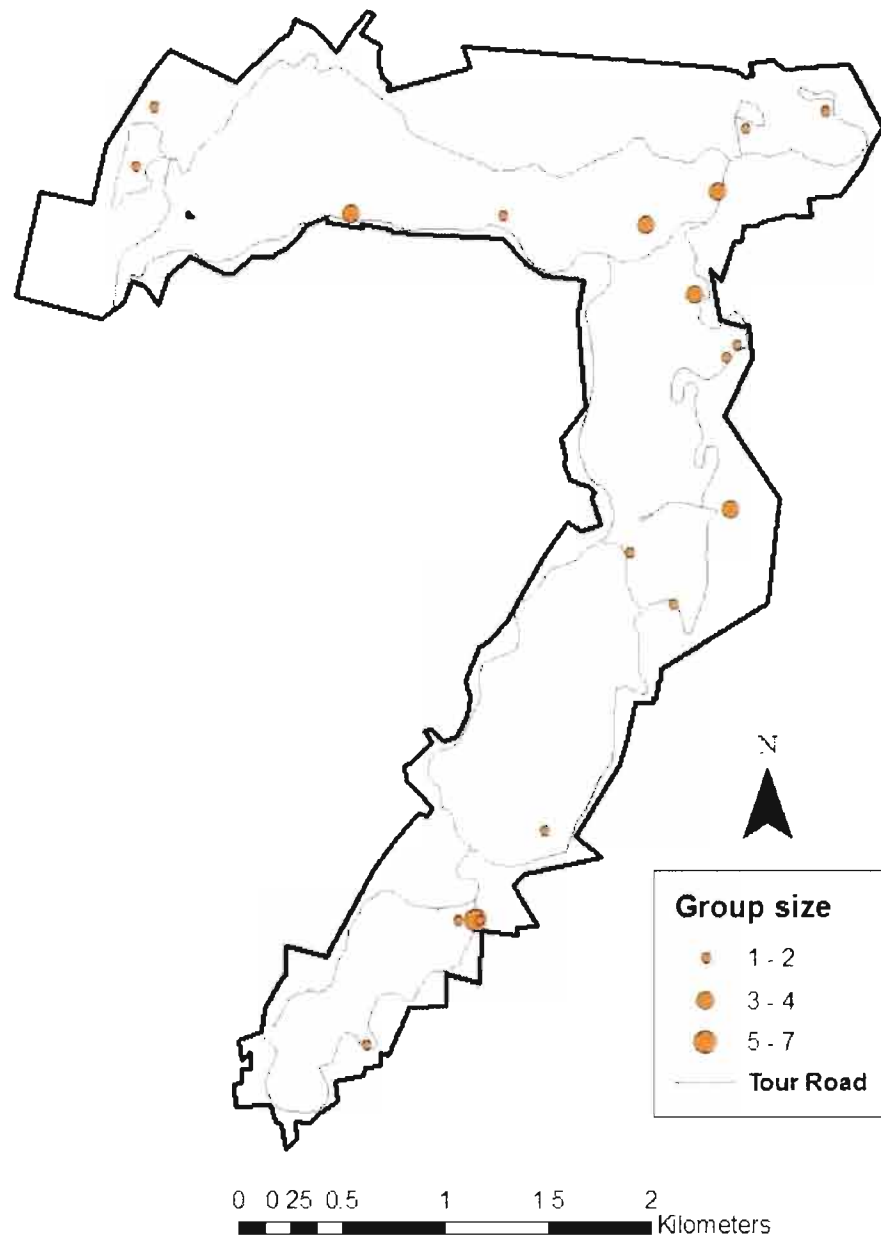


Figure A13. Locations of deer on Vicksburg National Military Park, 14 December 2008.

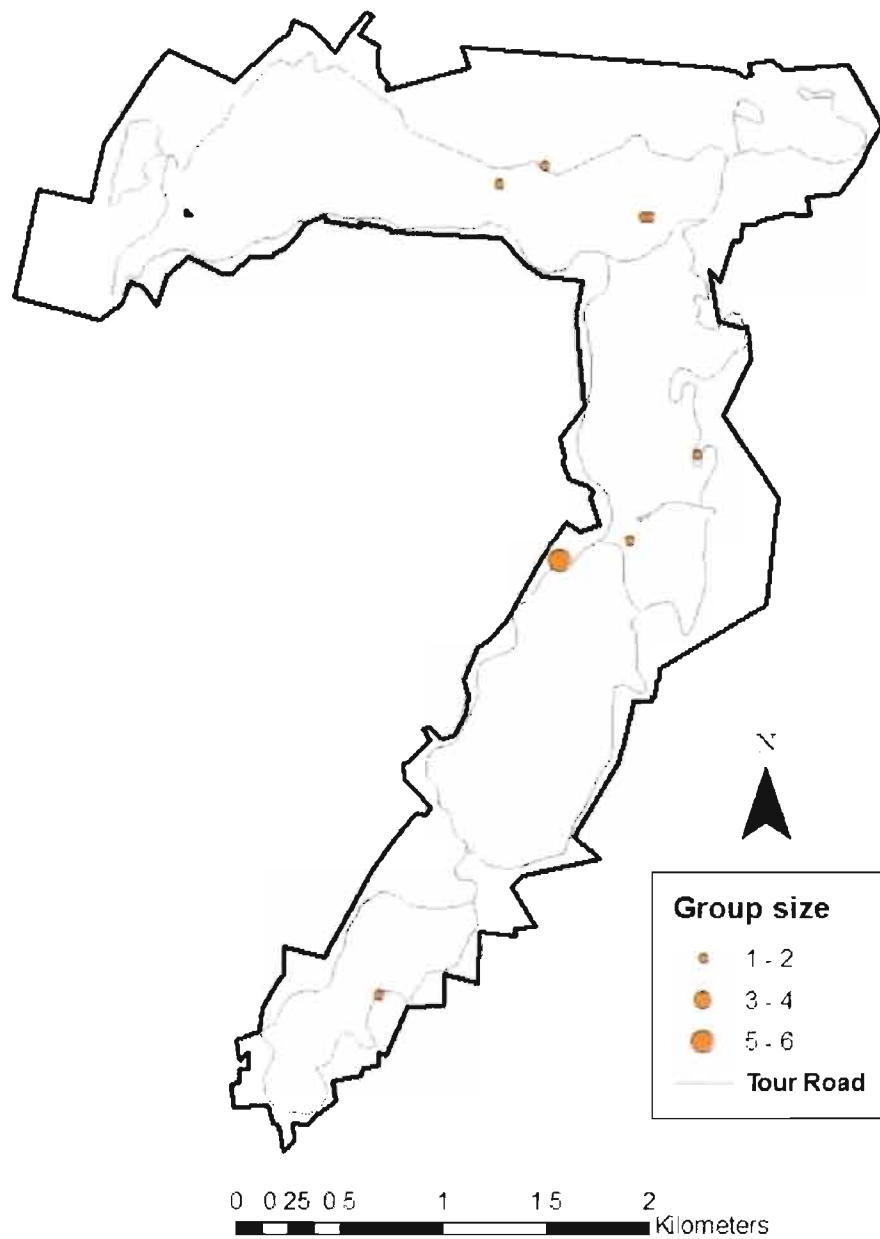


Figure A14. Locations of deer on Vicksburg National Military Park, 15 December 2008.

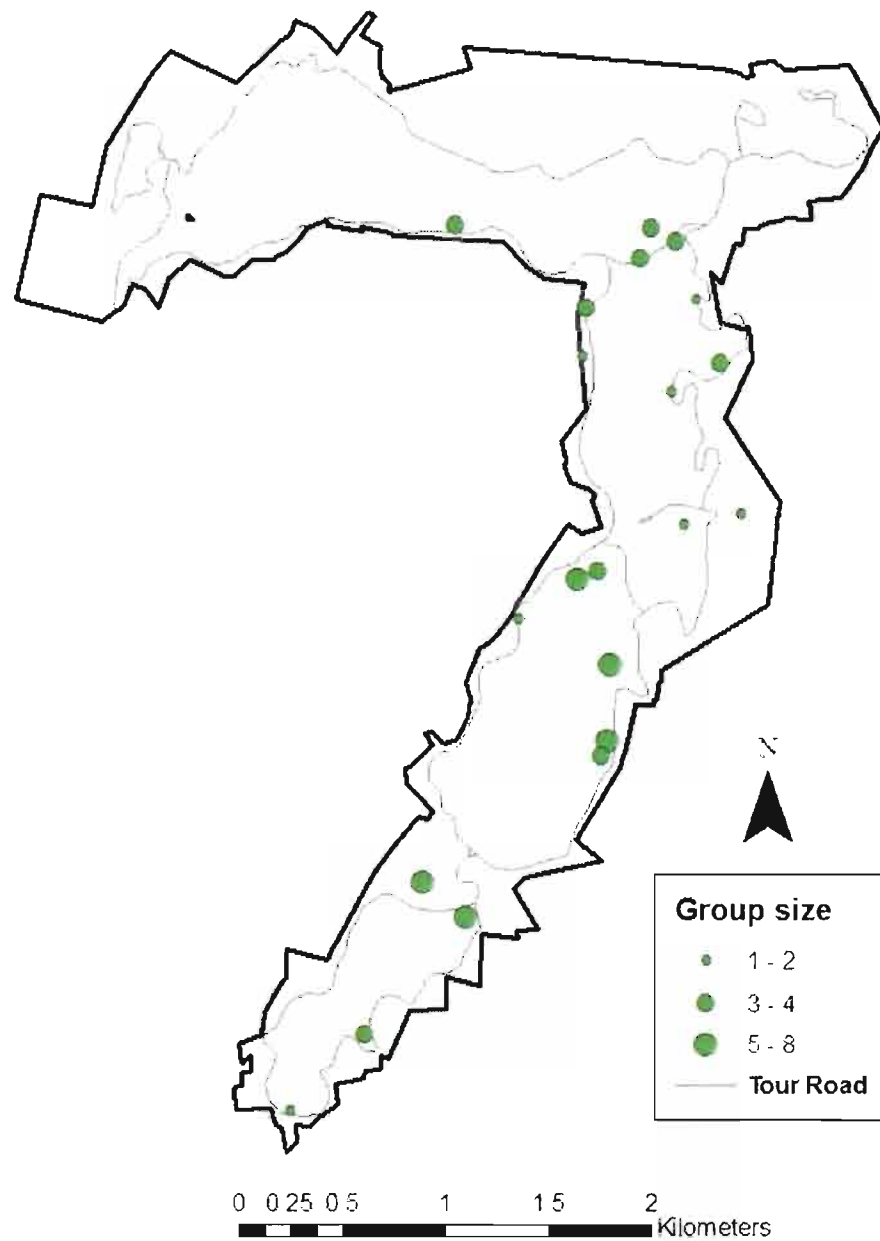


Figure A15. Locations of deer on Vicksburg National Military Park, 3 March 2009.

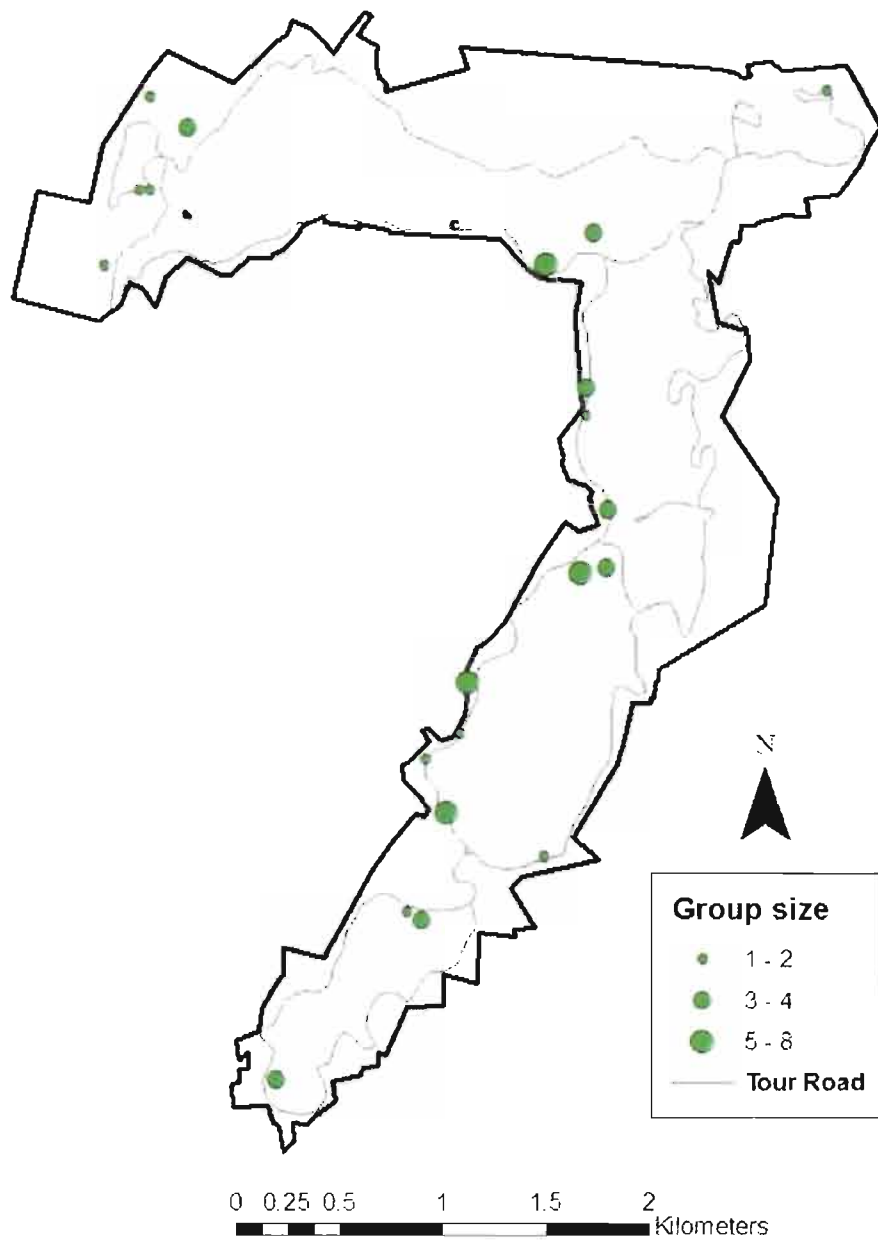


Figure A16. Locations of deer on Vicksburg National Military Park, 4 March 2009.

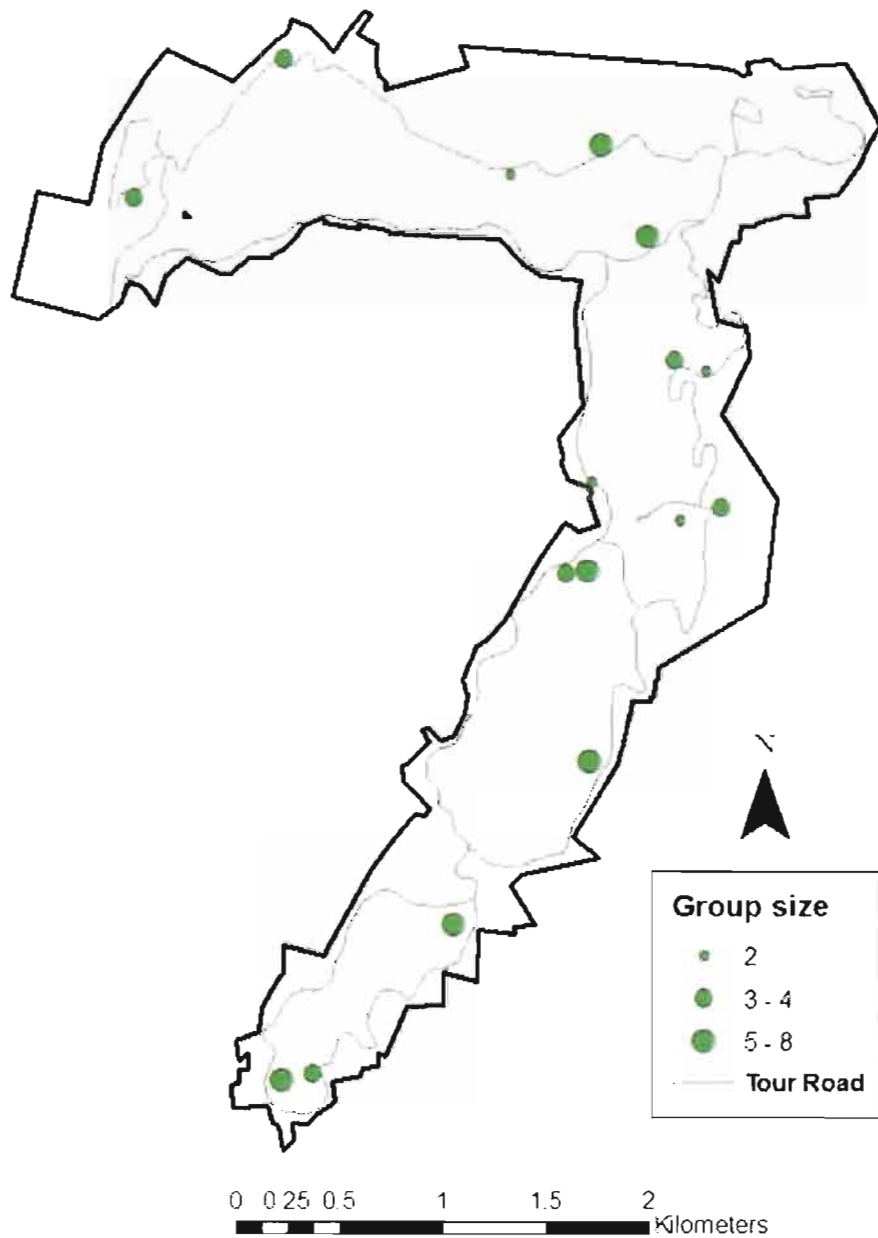


Figure A17. Locations of deer on Vicksburg National Military Park, 5 March 2009.

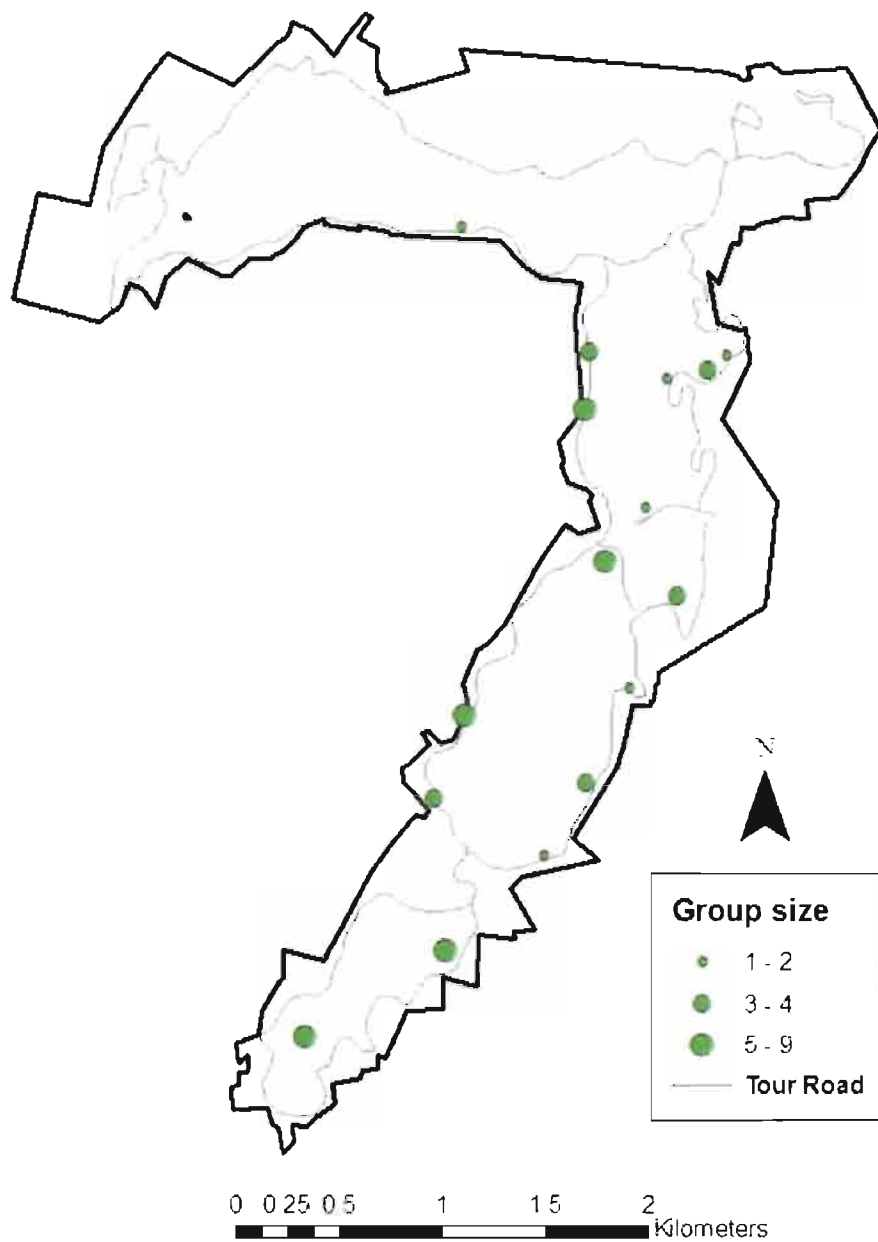


Figure A18. Locations of deer on Vicksburg National Military Park, 6 March 2009.

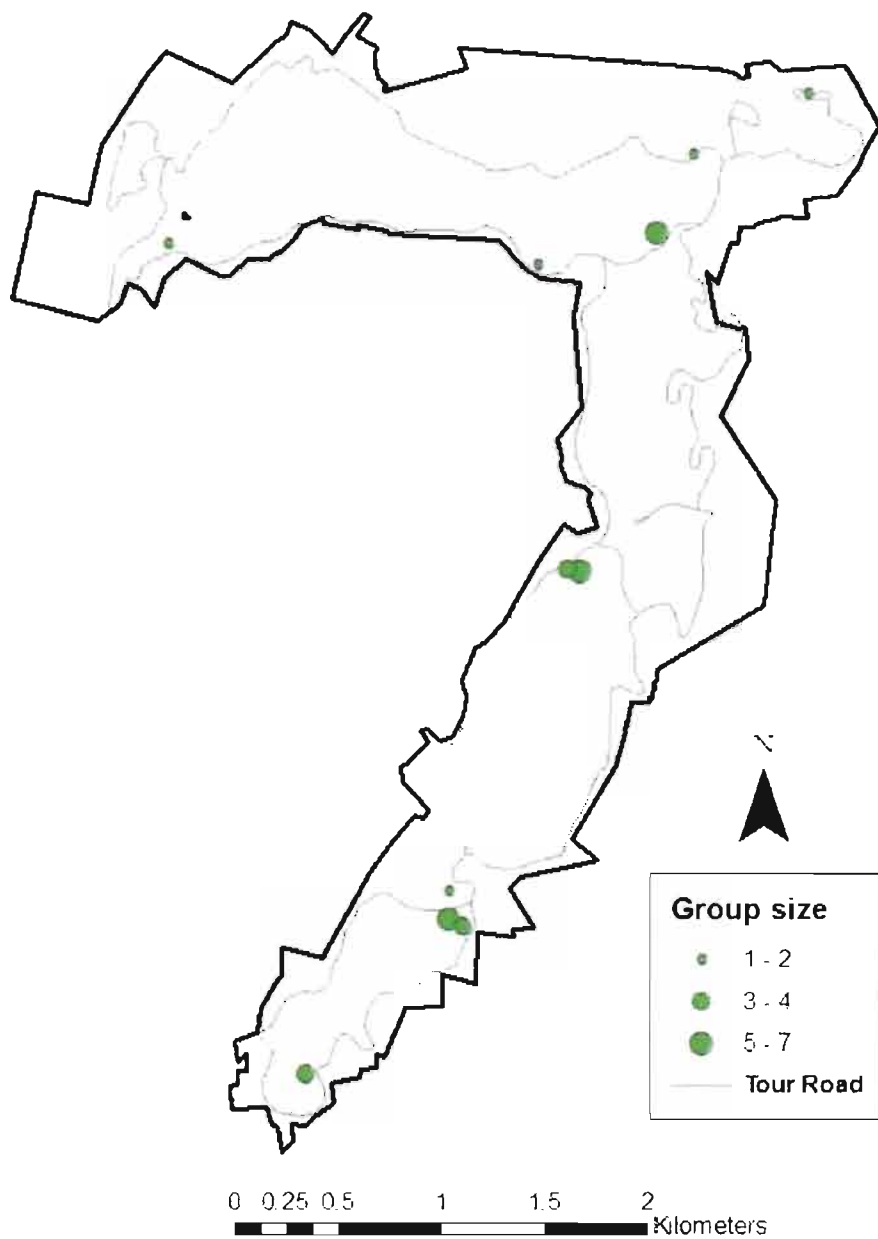


Figure A19. Locations of deer on Vicksburg National Military Park, 7 March 2009.

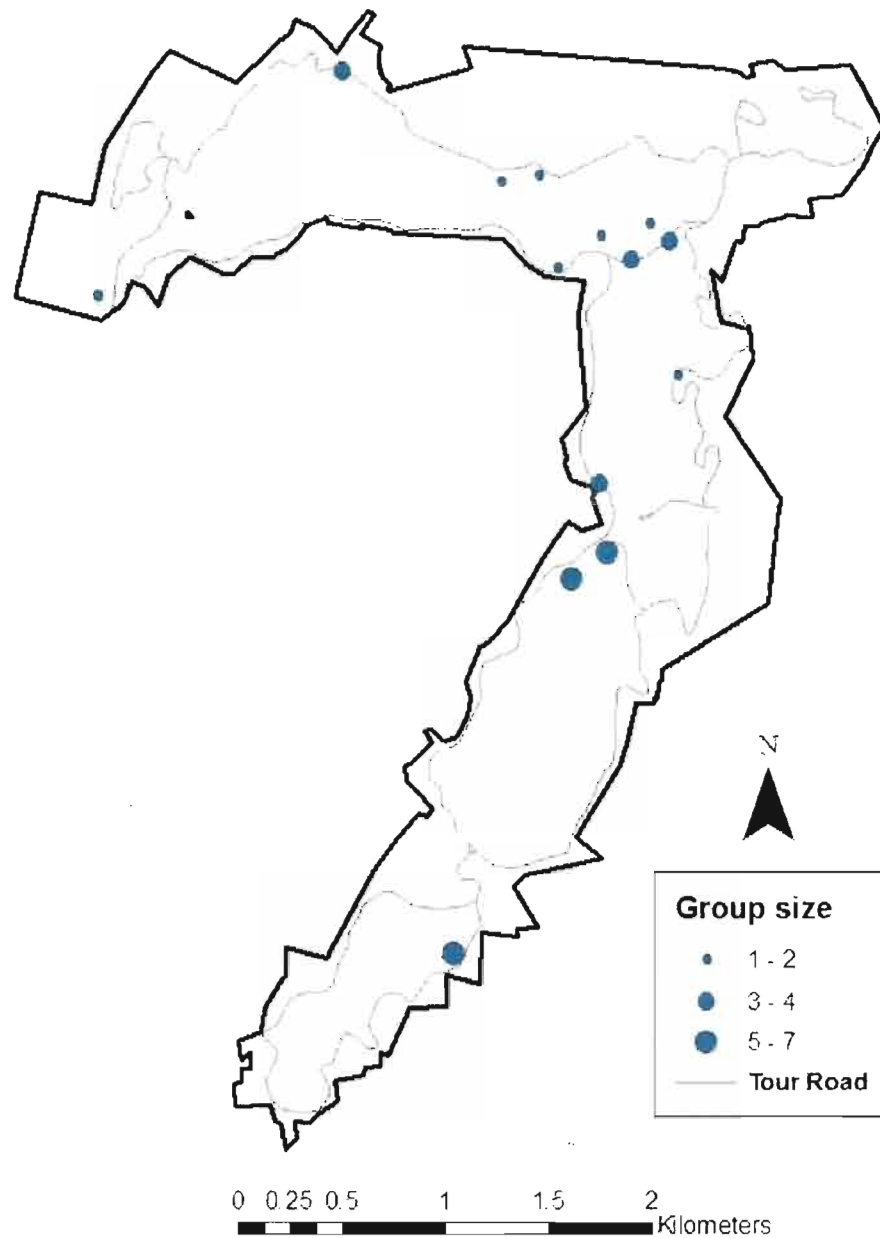


Figure A20. Locations of deer on Vicksburg National Military Park, 12 May 2009.

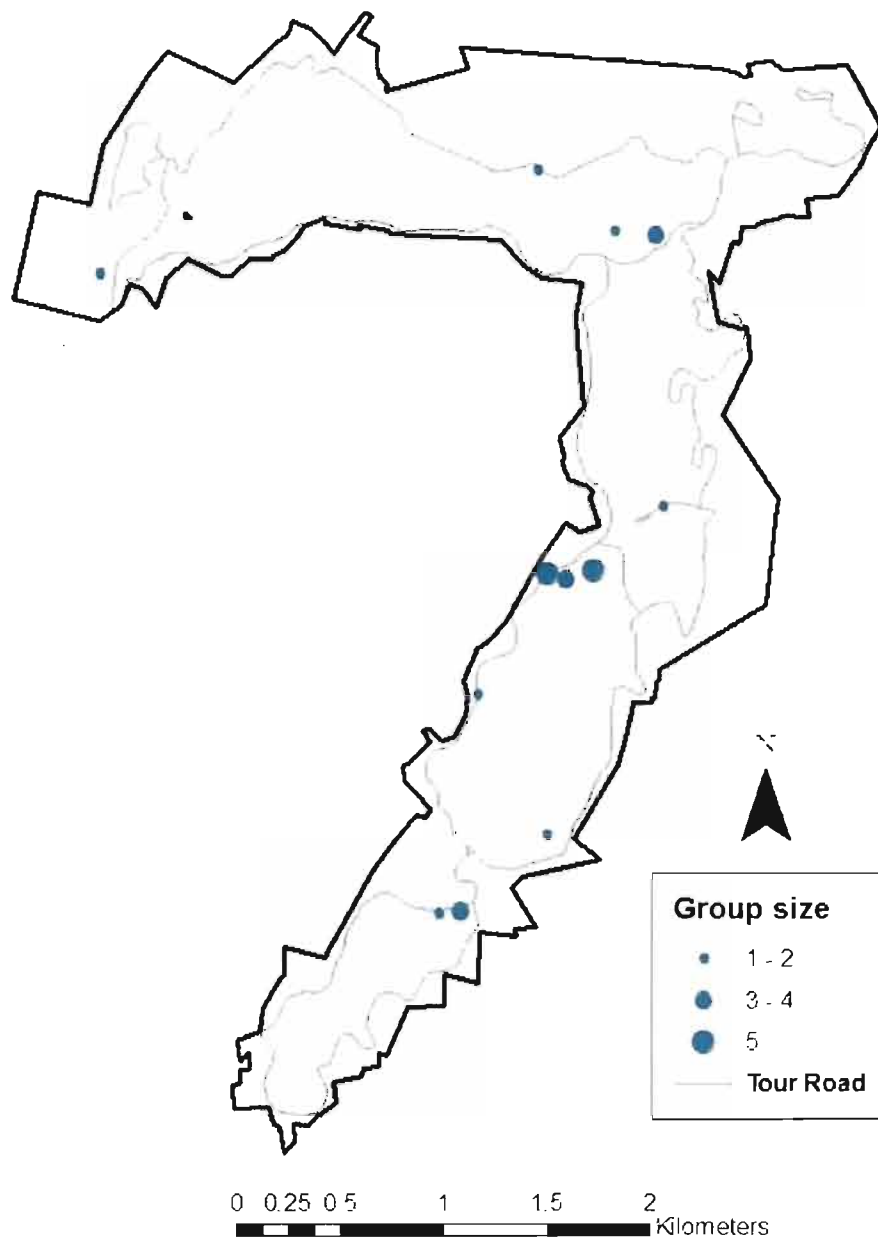


Figure A21. Locations of deer on Vicksburg National Military Park, 13 May 2009.

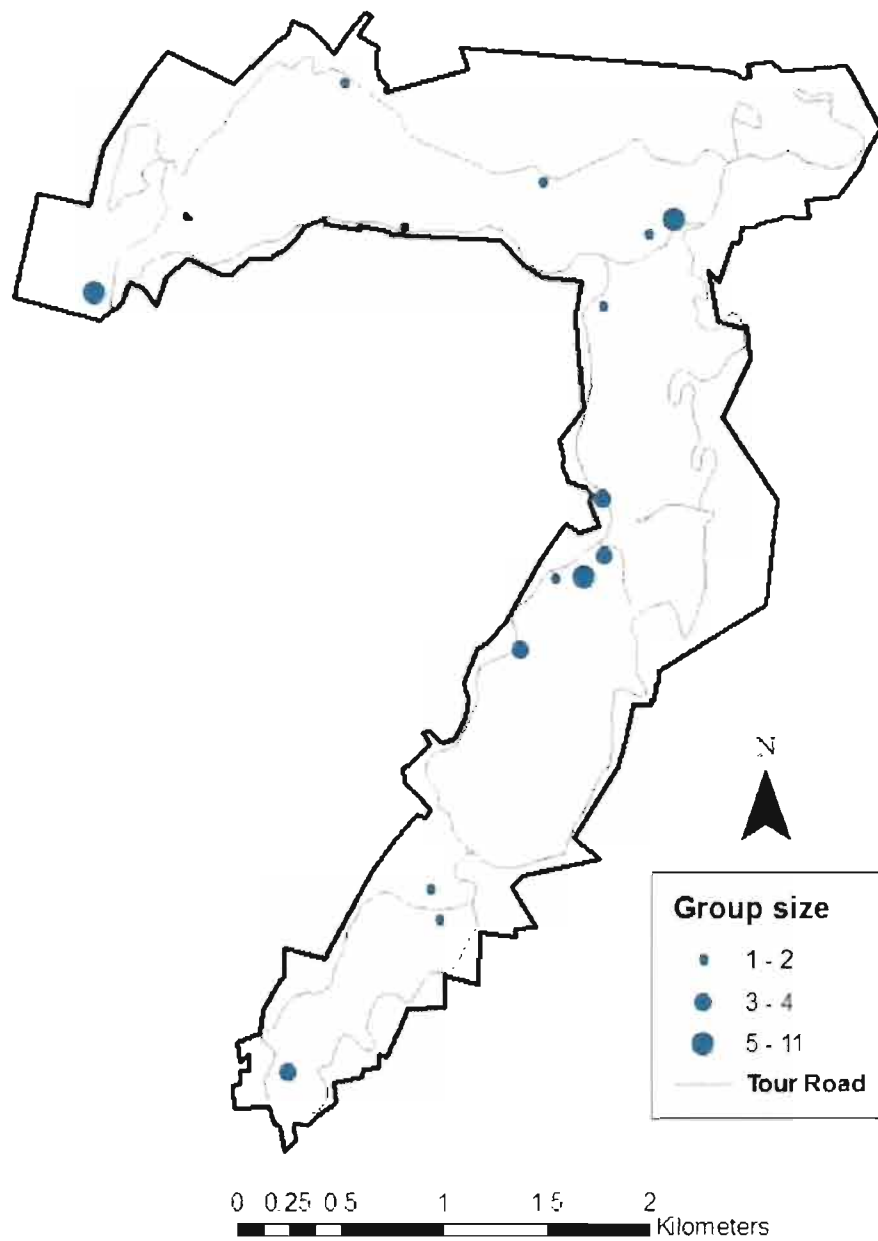


Figure A22. Locations of deer on Vicksburg National Military Park, 14 May 2009.

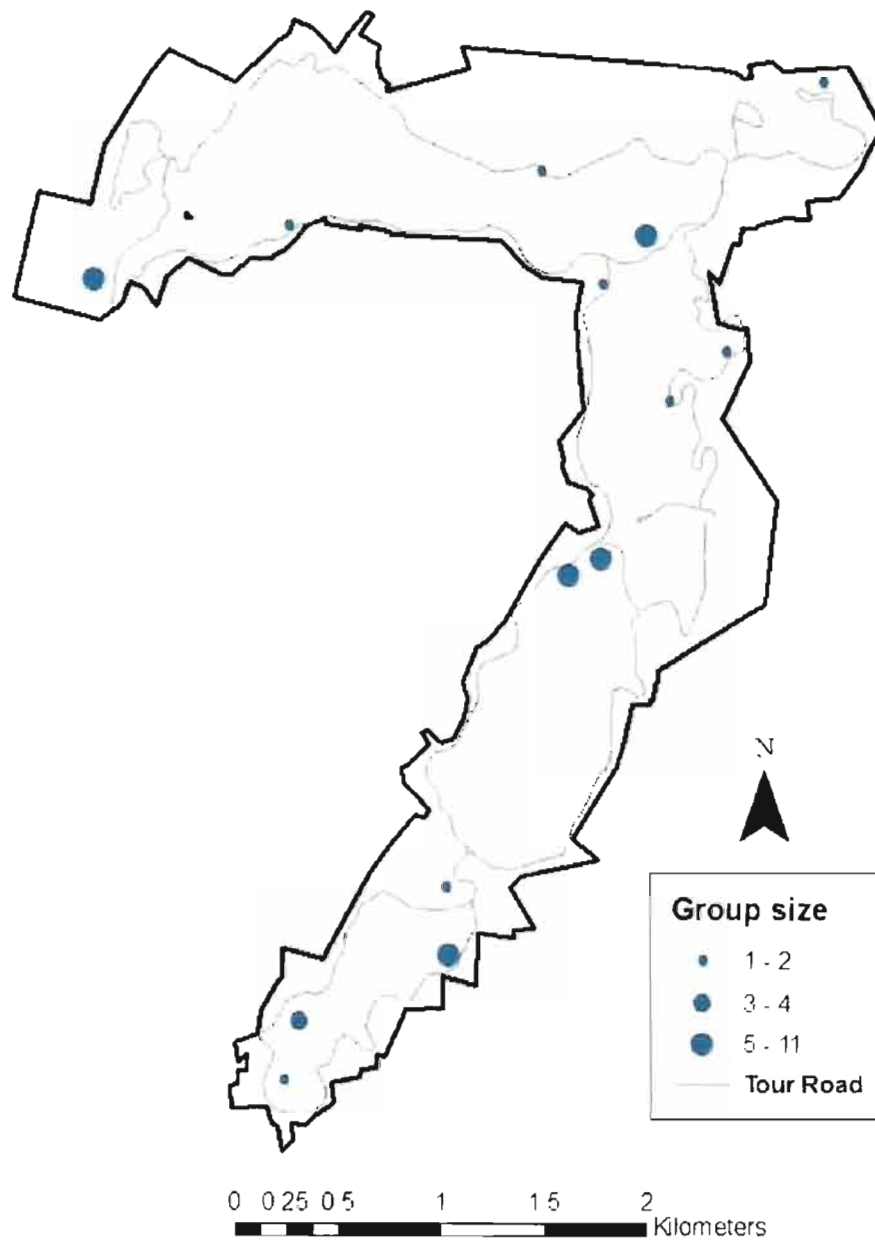


Figure A23. Locations of deer on Vicksburg National Military Park, 15 May 2009.