MOVEMENT AND MORTALITY OF WHITE-TAILED DEER IN SOUTHWEST MINNESOTA

BY

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MOVEMENT AND MORTALITY OF WHITE-TAILED DEER

IN SOUTHWEST MINNESOTA

This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

MOVEMENT AND MORTALITY OF WHITE-TAILED DEER IN SOUTHWEST MINNESOTA

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Knowledge of survival rates, causes of mortality, and information related to movements are essential in understanding the population dynamics of white-tailed deer (*Odocoileus virginianus*). In addition, proper deer management requires an understanding of fawn mortality from birth to recruitment. No direct information is available on population dynamics of deer in intensively cultivated areas in southwest Minnesota. Primary objectives were to determine seasonal survival rates, seasonal movement, and cause-specific mortality (e.g., hunting, vehicle collision, predation, disease) of white-tailed deer in southwest Minnesota. Secondary objective was to estimate seasonal home ranges. During 2001-02, radio telemetry was used to monitor the movement and mortality of 61 adult (>1 year at capture), 16 fawn (~8 months at capture), and 39 neonate (<1 month at capture) white-tailed deer. From January 2001- August 2002, 6,867 deer locations were collected with a mean 95% error ellipse of 3.83 ha. Deer had two seasonal home ranges, winter and summer. Mean home range size was 5.18 km^2 (n = 37, SE = 0.78) during winter and 2.27 km^2 (n = 93, SE = 0.18) during summer. Deer occupied summer range for approximately 7 months, arriving from winter range during mid-April and departing to winter range during late November. Mean distance migrated between seasonal ranges was 10.1 km (n = 95, SE = 0.70). Temperature and snow depth were the primary factors influencing seasonal migration in southwest Minnesota. Throughout the study, 14 female deer (10 adults, 4 fawns) died and the overall adult survival rate was 0.75 (n = 77, SE = 0.05). In southwest Minnesota, survival of adult female white-tailed deer was primarily dependant on human factors (i.e., hunting, vehicle collisions). Natural causes of mortality such as predation and disease (14.2%) were minor relative to human related causes (71.5%) for adult female deer. A total of six neonate mortalities (predation = 4, disease = 1, vehicle collision = 1) occurred during the study. Pooled summer neonate survival rate was 0.84 (n = 39, SE = 0.06). Adult female and neonate white-tailed deer populations had high survival and minimal vulnerability to death by natural causes in intensively cultivated areas. These data may be extrapolated to white-tailed deer herds in other highly fragmented regions with intensive cultivation, limited permanent cover, high hunter density, high road density, low predator density, and large fluctuations in seasonal climate. These factors were significant influences on movement and mortality of deer in southwest Minnesota. Data from this study will be used to improve Minnesota's farmland deer population model and assist wildlife managers with decisions concerning white-tailed deer management. A landscape-level approach is necessary to understand long-term trends and factors influencing deer densities across farmland Minnesota.

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CHAPTER 1

INTRODUCTION

BACKGROUND

Prior to settlement, Minnesota consisted of three primary vegetation zones; Forest (coniferous forest), Transition (deciduous forest/grassland mix), and Prairie (tall grass prairie; Rosendahl and Butters 1928; Fig. 1). Pre-settlement, white-tailed deer (*Odocoileus virgninianus*) were concentrated in the Transition Zone and wooded river valleys in the southwest portion of the Prairie Zone (Erickson et al. 1961). As primitive forests of the north were logged, thick secondary growth consisting of shrubs and small trees provided favorable deer habitat. By 1920, deer distribution increased in the Forest Zone (Erickson et al. 1961), while Transition and Prairie Zone deer numbers declined.

During the late 1800s, land clearing, intensified farming, market hunting, and unregulated harvest for subsistence extirpated deer in Transition and Prairie Zones. As a result, in 1923, deer hunting was banned in southern Minnesota (Erickson et al. 1961; Berner, A. H., unpublished data, Minnesota Department of Natural Resources). With legal protection, deer began to repopulate the southern and western parts of Minnesota. In the 1940's, hunting seasons were periodically opened in what is now known as the Farmland Zone (previously Prairie and Transition Zones). Eventually, with the expansion of the twin cities area (Minneapolis/St. Paul), Minnesota was separated into three wildlife zones; Forest, Farmland, and Metro (DePerno et al. 1999, Fig. 2). The Minnesota legislature and the Department of Natural Resources (DNR) adopted a deer management policy in 1974 that included the following set of deer management objectives: manage the deer population by maintaining the breeding population at the highest level the habitat and landowners will tolerate, allow maximum recreational opportunities tolerated by the deer population while minimizing landowner/hunter conflicts, have standardized, consistent season frameworks. With these objectives in place, by the late 1970's deer hunting occurred throughout Minnesota, and approximately 44% of annual harvest occurred in the Farmland Zone (Berner, A. H., unpublished data, Minnesota Department of Natural Resources). Currently, 500,000 hunters pursue white-tailed deer each year in Minnesota, harvest roughly 200,000 deer (Minnesota Department of Natural Resources 2002), and approximately 60% of the harvest occurs in the Farmland Zone (DePerno et al. 1999).

Deer populations in Minnesota are managed within 125 permit areas (PAs) through the allocation of hunting permits for the firearms deer season. Each PA has population goals based on carrying capacity and landowner tolerance (Lenarz and McAninch 1994). For large-scale management purposes, PAs located within the Farmland and Forest Zones are managed separately through the use of population models. The farmland deer population model and wildlife manager recommendations are used to estimate the number of anterless permits required to maintain the deer population within a goal range for each PA within the Farmland Zone.

Output from the deer model is based on animal density, which is determined by using four age/sex groups; adult males, adult females, fawn males, and fawn females. Initial population size, population structure (i.e., age/sex ratio), harvest data, summer and winter survival rates, reproduction data (i.e., pregnancy rate, fetuses per doe, fetus sex ratio), registration rate, illegal kill, and crippling loss are incorporated into the model. Reproduction data determines the number of individuals added, and hunting and non-hunting mortality determines number of deer removed. Hunting losses are calculated each year from deer registered by hunters, which is mandatory in Minnesota. Thus far, non-hunting mortality rates incorporated into the farmland model have been educated guesses based on information collected from the literature.

Because of the difficulty of monitoring animals that travel long distances, managers typically ignore dispersal, or assume that immigration and emigration are equal (Johnson 1994, Rosenberry et al. 1999). Similarly, Minnesota's farmland deer model also makes the assumption that emigration/immigration does not occur between PAs (DePerno et al. 1999). Although wildlife managers and research biologists in farmland Minnesota know this assumption to be false, empirical data to determine amount of movement that may be occurring across PA boundaries does not exist. Hence, educated guesses based on the literature must be used if the effects of dispersal across PA boundaries are to be incorporated into the model. Because movements (i.e., seasonal migration, home range patterns, dispersal) of white-tailed deer vary greatly over their geographic range (Marchinton and Hirth 1984, Demarais et al. 2000), educated guesses based on data collected elsewhere are not a reliable option. Region-specific, sound, empirical information is needed to effectively manage Minnesota's white-tailed deer populations.

Just as the rate of deer dispersal across PA boundaries is unknown, information is absent on whether deer migrate seasonally across Minnesota PA boundaries. Previous studies in the Northern Forest and Midwest Agricultural regions have estimated seasonal migration distances from 6-38 km (Verme 1973, Hoskinson and Mech 1976, Nixon et al.

2001, Sabine et al. 2002). Potentially in southwest Minnesota, a deer herd's summer range may be in a different PA than their winter home range. In this hypothetical situation, management strategies in one PA would influence adjacent PAs. To anticipate these effects, information on movements (e.g., migration timing, distance, direction) must be available.

JUSTIFICATION

Few wildlife species in North America are a more valuable public resource than white-tailed deer (Conover 1997). In Minnesota, big game hunting expenditures by residents exceeded $250 million in 1996 (United States Department of Interior, Fish and Wildlife Service 1998). The vast majority of those expenditures came from deer hunters, whom outnumber other big game hunters 36 to 1. Furthermore, there are intangible values associated with deer that are difficult to quantify, including the sense of well-being that people feel from knowing that deer are thriving in nature (Krutilla 1967). Conversely, deer likely cause more economic damage than any other wildlife species in North America (Fagerstone and Clay 1997). For example, in the 10 largest corn (*Zea mays*) producing states, deer damage exceeded $30 million in 1993 (Wywialowski 1996). Also, deer are rated the most problematic wildlife species by farm bureaus, state agencies, and extension agents (Conover and Decker 1991). Additional problems associated with high deer populations include increased disease transmission and vehicle collisions. For instance, the Minnesota Department of Natural Resources (MNDNR) estimated that 15,000 deer are killed by vehicles annually. Moreover, high deer numbers may negatively impact habitat for other wildlife species, such as songbirds (DeCalesta 1997, McShea and Rappole 2000).

The complexity of social and economic aspects of white-tailed deer management creates a dilemma for resource agencies. Wildlife managers in Minnesota strive to maintain deer populations at levels that meet hunter expectations, while minimizing conflicts with landowners. Identifying and maintaining this balance is difficult without reliable empirical information specific to deer in Minnesota.

Knowledge of survival rates, cause-specific mortality, and information related to movements are particularly important in understanding population dynamics of deer (Halls 1984, Nixon et al. 1991, DePerno et al. 2000). In addition, proper deer management requires data on neonate mortality from birth to recruitment (Huegel et al. 1985a). When managing a harvestable population, region-specific data are necessary to avoid overexploitation (Nelson and Mech 1986a, Van Deelen et al. 1997), and to develop management strategies that will be accepted by divergent groups interested in the species (Nixon et al. 2001).

As research has been compiled on white-tailed deer in the northern part of their range, it has become apparent that survival rates fluctuate regionally and seasonally with sex, age, and deer density (DelGiudice et al. 2002). Numerous studies have been conducted on white-tailed deer in forested (Kohn and Mooty 1971, Nelson and Mech 1986a, Mooty et al. 1987, Fuller 1990, DelGiudice 1990, 1998, DelGiudice and Mangipane 1998, Filipiak 1998, DelGiudice et al. 2002) and urban (Doerr et al. 2001, Grund et al. 2002) habitats in Minnesota. However, no direct information is available on population dynamics of deer in intensively cultivated areas in southwest Minnesota.

OBJECTIVES

To improve the accuracy and precision of Minnesota's farmland deer population model and assist wildlife managers with decisions concerning white-tailed deer management, the objectives of this study were to determine the movements and mortality of white-tailed deer in southwest Minnesota. Primary objectives were to determine seasonal survival rates, seasonal movement, and cause-specific mortality (e.g., hunting, vehicle collision, predation, disease). Secondary objective was to estimate seasonal home ranges. More specifically, for female deer captured as adults (>1 year) and fawns (~8 months), objectives were to calculate seasonal, annual, and overall (i.e., 20 month study) survival rates, and to determine seasonal movements (i.e., migration, dispersal) and home ranges. For male and female deer captured as neonates (<1 month), objectives were to calculate monthly and summer (June-August) survival rates. Cause-specific mortality was determined for adults, fawns, and neonates. As a pilot study, we attempted to capture and radiocollar coyotes (*Canis latrans*) with the objective of estimating predator density and determining predator movement within the neonate study area.

CHAPTER 2

STUDY AREA AND SITE SELECTION

IN SOUTHWEST MINNESOTA

STUDY AREA

This study was conducted in a 34,627 km^2 area of southwest Minnesota (43º 29' N to 45º 16' N – 093º 38' W to 096º 27' W) containing 20 counties and 24 deer PAs (Fig. 3). Southwest Minnesota is composed of a highly fragmented landscape dominated by cultivated land (85.6%, Table 1). For this study, cultivated land was defined as "areas under intensive cropping or rotation, including fallow fields and fields seeded for forage or cover crops that exhibit linear or other patterns associated with current tillage" (Minnesota Department of Natural Resources 2000). According to the Minnesota Agricultural Statistics Service (2002), corn and soybeans (*Glycine max*) consist of 96.0% of the harvested cropland in the 20 county region of southwest Minnesota (Fig. 4), with the other major harvested crops being hay (3.0%; e.g., alfalfa [*Medicago sativa*]), wheat (*Triticum aestivum*; 0.7%), and oats (*Avena sativa*; 0.3%).

Grassland (6.5%), forest (3.0%), permanent bodies of water (1.6%), and wetlands (0.8%) are the other major land use/cover types (Table 1, Minnesota Department of Natural Resources 2000). In nature preserves, isolated pockets, and poor agricultural sites (e.g., steep slopes, poorly drained sites, infertile soils), native tallgrass prairie exists, commonly consisting of big bluestem (*Andropogon geradii*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), tall dropseed (*Sporobolus asper*), and sideoats grama (*Bouteloua curtipendula*) (Johnson and Larson 1999). In forested areas, dominant overstory vegetation includes eastern cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), basswood (*Tilia americana*), and bur oak (*Quercus macrocarpa*)

(Minnesota Association of Soil and Water Conservation Districts Forestry Committee 1986).

Southwest Minnesota is characterized by a flat to rolling topography with elevation ranging from 229 to 608 m above sea level (Albert 1995). The region has a sub-humid continental climate, with great differences between winter and summer temperature. At Marshall, Minnesota, which lies roughly in the center of the study area, average temperatures (1971-2000) equal –9.8 C° in January and 23.1 C° in July, and average annual precipitation and snowfall is 65.4 cm and 105.2 cm, respectively (Midwest Regional Climate Center 2002).

In southwest Minnesota, the white-tailed deer is the only free-ranging cervid. Coyotes, bobcats (*Lynx rufus*), and dogs (*Canis familiaris*) are the primary predators in this region. Sightings of wolf (*Canis lupus*) and mountain lion (*Puma concolor*) have been reported in the region, but occurrences are rare.

To select individual sites for deer capture within the study area, ArcView (ESRI, Redlands, CA) was used to calculate the percentage of cultivated land, grassland, and forest cover in each PA in southwest Minnesota. The MNDNR Minnesota Land Use/Cover data set (Minnesota Department of Natural Resources 2000) was used and cluster analysis was performed to classify permit areas into distinct groups based on land cover (Johnson 1998). A permit area was chosen from each cluster to appropriately represent major habitat types present throughout the southwest study. The objective of study site selection was to maximize the variation of the habitats throughout the southwest Minnesota region. Also, logistics such as travel time between sites were considered when selecting study sites. A fixed-wing aircraft was used to locate sufficient winter deer concentrations to meet study sample goals within each study site. The white-tailed deer neonate survival study was conducted at the closest study site to South Dakota State University (SDSU), Brookings, South Dakota. Analyses were performed using SAS (1999) and SYSTAT (Wilkinson 1990).

Using cluster analysis, a hierarchical cluster tree was constructed to identify how PAs are connected and the order in which they are assigned to clusters (Fig. 5). The average distance between clusters (x axis) was defined as "the average of all the dissimilarities between all possible pairs of points such that one of each pair is in each cluster" (Johnson 1998). We determined the cluster tree had three major branches containing one large and two small clusters (Fig. 5). Next, a principal components analysis was performed to plot scores and "fine tune" the clustering process. Three distinct clusters were identified (Fig. 6). Taking into consideration logistics (e.g., travel time between sites) and assignment on the cluster tree, permit areas 435, 450, and 451 were chosen from clusters to capture the greatest habitat variance across southwest Minnesota (Fig. 7). Permit area 435 contained the second highest percentage of forest land cover, PA 450 contained the second highest percentage of cultivated land cover, and PA 451 contained the second highest percentage of grassland/shrub in southwest Minnesota (Table 1). Sufficient deer winter concentrations were located near the cities of Redwood Falls (PA 435), Walnut Grove (PA 450), and Lake Benton (PA 451) Minnesota (Fig. 4). Because of the minimal distance (~45 km) between the Lake Benton study site and SDSU, this site was chosen to conduct the neonate survival study (Fig. 8).

Permit areas contained distinct differences in cultivated, forest, and grassland cover (Table 1). Permit area 435 was selected because of the high percentage of forest cover (7.3%, Table 1). This was due to the location of the Minnesota River Valley, the major river system in southwest Minnesota, which runs directly through PA 435. Overstory vegetation within the river valley was similar to that located elsewhere in southwest Minnesota, but was more concentrated and contained dense patches of willow (*Salix* sp.) in the river valley bottom (Albert 1995). Just above the river valley, the land cover was dominated by cultivated land (82.3%, Table 1). Deer capture in this area occurred in the Minnesota River Valley near the city of Redwood Falls (Redwood Falls study site, Fig. 4).

PA 450 was selected because of the high percentage of cultivated land and intensive corn and soybean agriculture. PA 450 was almost entirely cultivated land (93.4%) with small areas of grassland (2.4%) and forest cover (1.8%, Table 1). Deer capture occurred near the city of Walnut Grove (Walnut Grove study site, Fig. 4).

PA 451 was chosen because of the higher than average, relative to the rest of the study area, percentage of grassland (14.6%) and relatively low percentage of cultivated land (81.1%, Table 1). Deer capture occurred near the city of Lake Benton (Lake Benton study site; Fig. 4).

Because of the Lake Benton study site's proximity to SDSU, this site was chosen to conduct the white-tailed deer neonate survival study (Fig. 8). During deer parturition (late May, early June) in Minnesota, crops (e.g., corn, soybeans) are beginning to emerge during early June (Minnesota Agricultural Statistics Service 2002). Less than 20% of the land provides suitable cover for fawning, and habitat available for fawning was composed of small patches of grassland and tree groves. Tree groves were primarily shelterbelts and abandoned farmyards with ground vegetation consisting mainly of smooth brome (*Bromus inermis*). Shelterbelts consisted of spruce (*Picea* sp.), cedar (*Juniperus* spp.), Douglas fir (*Pseudotsuga menziesii*) and silver maple (*Acer saccharinum*) (Minnesota Association of Soil and Water Conservation Districts Forestry Committee 1986).

CHAPTER 3

SURVIVAL OF FEMALE WHITE-TAILED DEER IN SOUTHWEST MINNESOTA

INTRODUCTION

Knowledge of survival and cause-specific mortality is crucial to understanding white-tailed deer population dynamics. Numerous radiotelemetry studies have demonstrated that mortality differs regionally and seasonally with sex, age, and density of deer (Gavin et al. 1984, Dusek et al. 1992, Whitlaw et al. 1998, DePerno et al. 2000, DelGiudice et. al. 2002). Also, influence of human-related factors (e.g., legal harvest, poaching, vehicle collisions), weather conditions (e.g., winter severity), and predators on deer populations may vary (Nelson and Mech 1986b, Fuller 1990). With numerous fluctuating variables impacting deer dynamics, spatial and temporal-specific mortality estimates are essential for proper white-tailed deer management. Increased use of regional population models (Fuller 1990) designed to predict temporal changes in deer populations has stressed the importance of sound empirical data (Grund 2001). Without such data, overexploitation of hunted populations is possible (Hoskinson and Mech 1976, Nelson and Mech 1981, 1986a, Fuller 1989, Delgiudice 1998).

Survival and cause-specific mortality of white-tailed deer has been well documented in forested areas of Minnesota (Hoskinson and Mech 1976, Nelson and Mech 1984, Fuller 1990, DelGiudice et al. 2002), but minimal information has been collected in agricultural areas of Minnesota. The only documented study on adult white-tailed deer mortality in farmland Minnesota was reported by Simon (1986). No direct information exists on survival and cause-specific mortality in intensively cultivated areas (>80% cultivated land cover) of Minnesota.

Deer in southwest Minnesota occupy a much different environment compared to other areas of Minnesota. Deer in highly fragmented, intensively cultivated areas of the Midwest have developed unique behaviors to adapt to the landscape (Sparrowe and Springer 1970, Gladfelter 1984, Nixon et al. 2001). Farmland deer have, with minimal trouble, incorporated the annual growth and harvest of corn into habitat use, which provides temporary unlimited diurnal cover (Nixon et al. 1991). In nutrition-rich agricultural landscapes, food availability is often not a limiting resource, whereas forest cover may be limiting (Dusek et al. 1989). Farmland movements, such as seasonal dispersal, developed in response to agricultural landscapes, with many deer moving great distances to seek out habitat with suitable forest cover. Also, deer of the Agricultural Midwest Region experience less severe winter weather conditions than those of the northern forests (Gladfelter 1984, Blouch 1984). Compared to northern Minnesota, southwest Minnesota has a more intensive road network, lower deer density, less permanent cover, and less severe winter weather conditions (Grund 2001, DelGiudice et al. 2002). Furthermore, unlike southwest Minnesota, northern Minnesota has an established wolf population. Numerous studies have determined that wolves can significantly influence deer survival, especially during the winter (Hoskinson and Mech 1976, Nelson and Mech 1981, 1986b, Fuller 1989, Delgiudice 1998). Because of these differences, northern Minnesota survival and cause-specific mortality information for deer cannot be extrapolated to southwest Minnesota. To improve the accuracy and precision of Minnesota's farmland deer population model and assist wildlife managers with decisions concerning white-tailed deer management, the objectives of this study were to determine survival and cause-specific mortality of deer in southwest Minnesota.

A variety of techniques have been used to capture white-tailed deer including Stephenson box traps (Rongstad and McCabe 1984), Clover traps (Clover 1954), drive-netting (Beasom et al. 1980), cannon (rocket) nets (Hawkins et al. 1968), drop nets (Ramsey 1968), dart guns (Kilpatrick et al. 1997), and helicopter net-guns (Barrett et al. 1982). Numerous studies have compared and evaluated these capture methods (Hawkins et al. 1967, White and Bartmann 1994, Beringer et al 1996, DelGiudice et al. 2001, Haulton et al. 2001). Each technique has advantages and shortfalls. Therefore, the capture method chosen should be sit and study specific.

The goal of the southwest Minnesota adult white-tailed deer capture was to radiocollar 20 animals in each of three study sites (i.e., total sample size = 60 individuals). Ideally, all animals were to be radiocollared at approximately the same time so that the starting period for survival and movement analyses was equal among study sites. Due to logistics (e.g., set-up time, travel time between sites), ground capture methods (e.g., Clover traps, Stephanson box traps, cannon nets) was not a viable option if deer were to be captured simultaneously across study sites. Therefore, to meet study needs, capture by use of net-guns deployed from helicopters was most appropriate for this study.

Advantages of helicopter net-guns include quick and accurate deployment which results in short capture and processing times (Firchow et al. 1986, Kock et al. 1987). During a mule deer (*Odocoileus hemionus*) fawn study, White and Bartmann (1994) reported that net-gunning required 98% less person-days than drop netting. Along with shorter chase-time, there is selectivity potential with net-gunning (Krausman et al. 1985). Because we were radiocollaring only female deer, selectivity was particularly important for this study.

Helicopter net-gunning has been identified as an efficient means of capture without sacrificing the welfare of the animal. Kock et al. (1987) noted that use of net-guns resulted in the lowest percentage of capture stress, lowest risk of capture myopothy, and lowest risk of overall mortality compared to three other capture methods used in a bighorn sheep (*Ovis canadensis*) study. Furthermore, in a mule deer fawn study, net-gunning was reported to be a safer capture method than drop nets (White and Bartmann 1994). In addition, helicopter net-gunning can be conducted without chemical immobilization, thus avoiding the negative effects of drugs (Amstrup and Segerstrom 1981).

METHODS

Female white-tailed deer were netted from a helicopter at winter deer concentrations near the cities of Lake Benton, Walnut Grove, and Redwood Falls (Fig. 4). Upon capture, a crewmember exited the helicopter and restrained, hobbled, and blindfolded the deer to minimize stress. Deer were transported to a processing site where blood samples were collected by venipuncture of the jugular vein for disease evaluation and physical condition of deer was assessed. Rectal temperature was continuously monitored as an indicator of stress. If temperature exceeded 40 C°, snow or bags of ice were packed along the underside of deer to stabilize or reduce body temperature. If the temperature did not stabilize or decline, deer were released. Captured deer were aged as fawn (~8 months) or adult (>1 year), measured (chest and neck circumference [cm]), ear-tagged, and administered an intramuscular injection of a broad-spectrum antibiotic. Radiocollars (Advanced Telemetry System, Isanti, Minnesota) equipped with activity and mortality sensors were placed around the neck of deer, and were set to switch to mortality mode after the transmitter had remained still for 8 hours. After processing, hobbles and blindfolds were removed and deer were released. Total handling time and distance from the capture location to the processing site were recorded for each deer. All methods used in this research were approved by the Institutional Animal Care and Use Committee at SDSU (Approval number 00-A038).

Individual, radiocollared adult deer were monitored for mortality 2-3 times per week using a vehicle mounted "null-peak" antenna system (Brinkman et al. 2002). Cause of death was determined from field necropsy and ancillary evidence at the deer location (White et al. 1987). If cause of death could not be determined in the field, carcasses were transported to the SDSU Animal Disease Research Diagnostic Laboratory (ADRDL) for further investigation. To verify age of each deer, lower incisors of adults were collected post-mortem. Capture-related mortalities were censored from survival analysis. We assumed mortality occurring <26 days post-capture was related to capture and handling of deer (Beringer et al. 1996). To coincide with the Minnesota farmland deer population model (Ch. 1), seasonal survival rates were separated into three time periods; pre-hunt (1 May - 31 August), hunting (1 September - 31 December), and post-hunt (1 January - 31 April). Hunting season was further divided into two categories; hunting and hunting-all. Hunting included only legal harvest mortalities in the survival rate, and hunting-all included all mortalities (e.g., vehicle, predation) occurring during that time period.

Survival rates of white-tailed deer were calculated using the Kaplan-Meier procedure (Kaplan and Meier 1958) modified for a staggered entry design (Pollock et al 1989). Annual and overall (20-month) survival rates were calculated by age (adult, fawn), season, and study site, and compared using Program CONTRAST (Hines and Sauer 1989). Statistical analyses were performed using SYSTAT (Wilkinson 1990). Alpha was set at $P \leq 0.05$, and a Bonferroni correction factor was used to maintain the experiment-wide error rate when multiple Chi-squared and *t*-tests were performed (Neu et al. 1974).

RESULTS

During 22-24 January 2001, 58 female deer (44 adult, 14 fawn) were captured and fitted with radiocollars (Table 2, Appendix A). To replace animals that died during the first year, an additional 19 female deer (17 adult, 2 fawn) were captured and radiocollared on 26 January 2002 (Table 3, Appendix B). A total of 28 deer was captured at Lake Benton, 30 at Walnut Grove, and 19 at Redwood Falls study sites (Fig. 4).

Two capture related injuries occurred during helicopter net-gunning operations. During 2001, an adult female broke the left front metacarpal bone. This injury was discovered after release. After capture, the movements of this deer were consistent with other radiocollared deer at this site. This animal died from a vehicle collision approximately 6 weeks post-capture. Influence of the capture related injury on mortality was unknown, therefore, the individual was censored from the study. In 2002, an adult female sustained a ruptured vertebrae and shattered pelvis (determined via necropsy) during helicopter operations. This animal was euthanized at the processing site.

Total time spent handling each deer averaged 8.2 minutes (8.6 minutes in 2001 [Table 2, Appendix A], 6.8 minutes in 2002 [Table 3, Appendix B]), and varied between 4.0 - 15.0 minutes. Reduced handling time during 2002 capture operations was attributed to a more experienced processing crew. Distance between capture location and processing site averaged 1.7 km (1.6 km in 2001, 2.0 km in 2002), and ranged between 0.0 – 4.5 km. Rectal temperature ranged from 38.9 to 42.2 C° with a mean of 40.6 C° (n = 77, SE = 0.08; 40.6 C° in 2001, 40.8 C° in 2002). Rectal temperatures were similar between years (df = 1, t = -1.05, P = 0.2663), but differed (df = 1, t = -3.33, P = 0.0030) between adults and fawns. Adult and fawn neck circumference averaged 43.7 and 35.2 cm, respectively, and ranged from 29.0 to 52.0 cm. Average chest circumference was 106.6 cm for adults and 86.9 cm for fawns and ranged from 122.0 to 77.0 cm. Chest-girth measurements were used to predict live weight of captured deer. Equations provided by Weckerly et al. (1987) were $\hat{Y} = -15.97 + 0.08X$ for adult females and $\hat{Y} = -19.12 + 0.07X$ for fawns during the winter season. These equations indicated that average live weight at capture for adults was 69.33 kg and 41.69 kg for fawns. These live weight predictions indicate that deer were in excellent condition in southwest Minnesota when compared to other populations (Kie et al. 1983, Verme and Ullrey 1984).

Blood samples were collected from 64 deer and screened for Epizootic Hemorrhagic Disease (EHD), Bovine Tuberculosis (*Micobacterium bovis*), Bovine Viral

Diarrhea (*Pestivirus* spp.), Infectious Bovine Rhinotracheitis, Anthrax (*Bacillus anthracis*), Leptospirosis (*Leptospira interrogans*), Bovine Brucellosis (*Brucella* spp.), Anaplasmosis (*Anaplasma* spp.), Toxoplasmosis (*Toxoplasma gondii*), Lyme disease, and Johne's disease (*Micobacterium paratuberculosis*).

Seventeen deer died during the 20-month (January 2001-August 2002) time period, and 14 were included in survival analyses (Table 4, Appendix C). Hunting was the greatest cause of mortality, with six (42.9%) deer killed by firearms hunters (Fig. 9; Table 7). In addition, 3 deer were killed by vehicle collisions (21.4%), one by train collision (7.1%), one by predator (7.1%), one by disease (7.1%), and two mortalities were from unknown (14.3%) causes. Median age of deer at death was 2.0 (n = 12; range = 8.0). Of the eight mortalities from non-hunting causes included in survival analysis, 50.0% occurred at Redwood Falls, 37.5% at Walnut Grove, and 12.5% at Lake Benton (Table 4, Appendix C).

A 2.5-year old deer died on 16 October 2001. The carcass was almost entirely cached under a fallen tree and covered with ground debris (e.g., leaves, grass, twigs; Fig. 10). A cache such as this one is typical behavior of bobcats and cougars, which will often cover a partially eaten deer carcass, and return to feed later (Connolly 1981, Mech 1984, Rezendes 1992). The deer's nose and two hoofs were the only visibly exposed parts of the animal. Abrasions penetrating the skin and causing extensive hair loss were present on the lower back and left hind quarters of the deer with claw marks penetrating into the flesh (Fig. 10). During attack, bobcats or cougars will often jump on a deer's back, grasping the shoulders or neck with front claws (Mech 1984). The claw marks present on the deer's rump may have been caused from the cat "raking" the deer with rear claws. The right front and rear legs were fed on to the bone. No other parts of the animal were consumed. Puncture marks were present on the throat with bruising and hemorrhaging under the skin, which is typical of a cat kill. Large prey, such as a deer, are killed with rapid bites to the throat, neck, or base of skull (Sunquist and Sunquist 2002).

The deer that died from disease was a 9-month-old female located dead on 19 February 2001 at the Walnut Grove study site. The fawn was lying in the fetal position on a snow-packed trail on property in which the landowner provided supplemental feed (i.e., corn) for deer during winter. Although temperatures were below 0 C°, the carcass of the fawn had not begun to freeze, and the joints were flexible. It was estimated the animal died within 12 hours. Externally, the doe fawn showed no signs of significant trauma. The carcass was transported back to SDSU and submitted to ADRDL the following day. Ancillary tests reported positive results for the presence of *Clostridium perfringens* type A in three sections of small intestine that were submitted to bacteriology. *Clostridium perfringens* induced enteritis was the suspected cause of death. However, severe autolysis of most organ systems, including in particular the gastrointestinal (GI) tract, prevented histologic evaluation necessary to confirm this diagnosis. Based on the gross findings of significant intestinal hemorrhage and the presence of abundant *C. perfringens* organisms from multiple sections of GI tract, the hemorrhage and enteritis are believed to be secondary to this anaerobic pathogen. There were no other significant histologic lesions observed in the tissues and organ systems examined.

Two mortalities of unknown cause occurred at the Redwood Falls study site during April 2001-02. In April 2001, significant autumn precipitation, heavy winter snowfall, less than ideal snowmelt scenarios, and record-breaking precipitation led to major flooding on the Minnesota River (MN DNR Division of Waters 2003). On 17 April 2001, a mortality signal was received from an adult female deer. Flooding prevented access to the estimated location of the deer. By 15 May, river levels receded to a level where the radiocollar could be retrieved. The deer was not present at the location of the radiocollar and no deer remains were located in the area. Several live signals were received from 17 April to 15 May 2001. This may be due to scavengers or fluctuating water levels moving the radiocollar, and thus, triggering a live signal. On 11 April 2002, a mortality signal was tracked to a floating log jam in the Minnesota River. The radiocollar was under water at an unknown depth and not retrievable due to river current and poor water visibility. No deer remains were located. Drowning may have potentially killed these deer. Two mortalities caused by drowning were reported by Nelson and Mech (1986a) in a study conducted in northeastern Minnesota and DePerno et al. (2000) reported a deer drowning in the Black Hills, South Dakota. However, because the deer carcass or remains of the deer were not present, confirmation of cause-specific mortality was not possible.

Eight deer were censored from survival analysis. In addition to the adult female that sustained an injury during capture, two fawns (~8 months) were censored from survival analysis because death may have been capture related (Appendix C). A predator killed fawn died 13 February 2001 at the Redwood Falls study site. Because the mortality occurred <26 days post-capture (Beringer et al. 1996), this deer was censored. During 2002 capture operations, there were complications with processing of a fawn at Redwood Falls. During release, the fawn repeatedly kicked at the radiocollar with her left hind leg, catching her hoof underneath the collar. After the third occurrence, the radiocollar was tightened and the deer was released without further problems. This fawn was discovered dead 4 days later. The carcass of the fawn was fed on and drag marks were present. During capture, this animal experienced a long handling time (12 min) compared to the average (8.6 min). Maximum rectal temperature during handling was 42.1 C°. Considering rectal temperature, handling time, and additional stress experienced by this deer, capture myopathy may have contributed to death and this deer was censored from survival analyses. An additional five deer were censored at varying times throughout the study because of failed radiocollars.

During 2001, annual survival rate of all radiocollared deer was 0.76 (n = 58, SE = 0.06; Table 5). Overall (Jan. 2001–Aug. 2002) survival was 0.75 (n = 77, SE = 0.05; Table 6). Annual survival across study sites was similar (df = 2, χ^2 = 3.362, P = 0.186; Table 5). Overall survival was 0.89 (n = 28, SE = 0.06) at Lake Benton, 0.73 (n = 19, SE = 0.11) at Walnut Grove, and 0.64 (n = 30, SE = 0.09) at Redwood Falls (Table 6). In 2001, survival differed between seasons (df = 3, χ^2 = 25.6914, P < 0.001). Pre-hunt, hunting, hunting-all, and post-hunt season survival were 1.0, 0.88, 0.80, and 0.95, respectively, in 2001 (Table 7). In 2002, seasonal survival rates during pre-hunt and post-hunt were 1.0 and 0.98, respectively. Overall adult survival was similar (df = 1, χ^2 = 0.475, *P* = 0.491) to fawn survival (Table 8).

Eleven deer that died during this study were observed through at least one migratory period. Of these deer, 91% exhibited migratory behavior; traveling between distinct winter and summer ranges. Survival for non-migratory individuals (0.89, *n* = 9, SE = 0.10) was similar (df = 1, χ^2 = 1.06, *P* = 0.304) to migratory individuals (0.77, *n* = 44, SE = 0.06). Mean migration distance (10.7 km, *n* = 10, SE = 2.5) of deer that died was similar (df = 1, χ^2 = 0.05, *P* = 0.8172) to mean migration distance of all radiocollared deer (10.1 km, *n* = 95, SE = 0.7).

DISCUSSION

Helicopter net-gunning was an efficient and safe method for capturing adult white-tailed deer. Seventy-eight female deer were captured (77 radiocollared) in 3.5 days (3.12 deer per hour) with one (1.3%) capture mortality, one (1.3%) capture related injury that may have influenced mortality, and two (2.6%) mortalities that may be due to capture myopathy. Capture-related mortality percentages were moderate to low compared to other ungulate capture operations using net-guns deployed from helicopters (12.0%, Barrett et al. 1982; 10%, Firchow et al. 1986; 2%, Kock et al. 1987; 0%, White and Bartmann 1994; 2%, DelGiudice et al. 2001).

According to the temperature boundaries discussed by Kreeger (1986), deer temperatures can be classified as low (<37.2 C°), normal (37.2 C° -39.4 C°), or high (>39.4 C°, DelGiudice et al. 2001). Using these guidelines, no captured deer were classified in the low range, 3.9% were classified in the normal range, and 96.1% would be classified in the high range. According to Kreeger (1986), cell damage begins at ≥40.0 C° and survival without adverse residual effects is unlikely if animals experience temperatures of 42.2 C°. Furthermore, Beringer et al. (1996) suggested that deer with higher temperatures during handling were at greater risk of capture myopothy. However, DelGiudice et al. (2001) determined no relation between rectal temperature and capture related mortality. Many deer captured during this study had rectal temperatures above 40.0 C° (Appendices A, B). Nevertheless, deer did not seem to be adversely affected by these high temperatures.

Although not statistically different (df = 1, t = -1.57, P > 0.130), mean transport distance was 0.4 km greater during 2002 than 2001 capture. Seasonal weather conditions may have contributed to this difference. Deer winter severity index (DWSI) was calculated in each study site by accumulating 1 point for each day with an ambient temperature ≤-7° C, and an additional point accumulated for each day with snow depths ≥35.0 cm (DWSI discussed in detail in Ch. 5). Combined DWSI value for December 2000 and January 2001 (61.4) was nearly three times greater than the DWSI for December 2001 and January 2002 (Figs. 11, 12, 13). Increased concentrations of deer in wintering yards in response to severe weather has been well documented among white-tailed deer in the northern part of their range (Blouch 1984). Therefore, a more widely distributed deer population in response to mild winter weather conditions during months prior to 2002 capture may have forced the helicopter crew to search a greater area to meet the sample size requirements.

Annual survival rate of adult female white-tailed deer (76%, Table 5) in southwest Minnesota was similar to survival rates reported elsewhere for female white-tailed deer (65%-80%, Gavin et al. 1984, Fuller 1990, Nixon et al. 1991, Whitlaw et al. 1998, DePerno et al. 2000). Furthermore, the annual mortality rate for female deer (22%) in southwest Minnesota was similar to that reported (average = 26%, range = 39.7%) for white-tailed deer in north-central Minnesota (DelGiudice 2000).

In southwest Minnesota, survival of adult female white-tailed deer was dependant on human factors (i.e., hunting, vehicle collisions). Natural causes of mortality such as predation and disease (14.2%) were minor relative to human related causes (71.5%, Fig. 9). Hunting was the greatest cause of mortality (43%) among females and was consistent with other northern white-tailed deer studies. In southern New Brunswick, most adult females died from hunting with a pooled annual mortality rate of 0.13 (Whitlaw et al. 1998). Fuller (1990) reported a hunting-related female mortality rate of 0.19 in northcentral Minnesota, with other causes of mortality being minor relative to hunting. Dusek et al. (1992) noted that 74% of female deaths were attributed to hunting, and only 8% were due to natural causes. In a mixed agricultural/forest landscape of southeast Minnesota, 86.4% of mortalities were hunter-related (Simon 1986). In heavily cultivated areas, such as southwest Minnesota, vulnerability to mortality by human related causes was likely due to the highly fragmented landscape with limited forest cover (Nixon et al. 1991), high hunter density (Hansen et al. 1997), and a well-established road network.

Majority of mortalities were concentrated during the hunting time period (Sept.-Dec.), and no deer died during the pre-hunt period (May – Aug.; Tables 4, 7).

Other studies have reported highest survival rates for female white-tailed deer during the summer months (0.90 – 1.0; Dusek et al. 1989, Fuller 1990, Nixon et al. 1991,Van Deelen et al. 1997, Whitlaw et al. 1998, DePerno et al. 2000). High summer survival (100%) in southwest Minnesota indicated that these results support Nixon et al. (1991) suggestion that high summer survival was likely due to condensed home ranges, unlimited food and cover (e.g., corn fields), and minimal human activities affecting survival.

DelGiudice (2002) noted that a severe winter (i.e., 1995-96) had "excessive" impacts on deer herds in northern Minnesota. Furthermore, Grund (2001) reported that survival rates were related to winter severity indices in central Minnesota. Because deer were monitored for one mild winter season and part of a moderate winter, and few deer mortalities occurred during this study, the direct influence of severe winter weather conditions on farmland deer survival was undetermined. DePerno et al. (2000) suggested low spring survival of female white-tailed deer in the Black Hills of South Dakota was attributed to poor quantity and quality of forage on winter range, and limited escape cover. In southwest Minnesota, high spring and summer survival may indicate that deer are maintaining a high nutritional plane through winter, and weather conditions had a minimal impact on survival.

All study sites were dominated by cultivated land, but differed in percentages of forest and grassland cover (Table 1, Ch. 2). Hansen et al. (1997) suggested that in landscapes under intensive row-crop agriculture, deer occupying areas with larger blocks (>1 km^2) of permanent cover are less vulnerable to harvest. Furthermore, Nixon et al.

(1991) noted that females living in larger forests had lower mortality rates. This was not apparent in southwest Minnesota. Lake Benton and Redwood Falls had similar percentages (~14 – 15%) of permanent cover (i.e., forest + grassland/shrub; Table 1), but Redwood Falls had more harvest mortalities (*n* = 3) than Lake Benton (*n* = 1). Two deer were harvested at Walnut Grove, which had the least permanent cover (4%). Also, most non-hunting mortalities occurred at Redwood Falls (*n* = 4), followed by Walnut Grove (*n* = 3), and Lake Benton (*n* = 1; Appendix C). However, due to the small number of mortalities (*n* = 14), effects of land use/cover variability between study sites on survival were speculative at best. Because of high survival across sites, it was concluded that minor fluctuations in percentage of permanent cover (±6%) had negligible influences on adult female white-tailed deer mortality in fragmented landscapes with >80% cultivation. However, additional research would increase sample sizes to levels where influences of land cover characteristics on survival in southwest Minnesota could be identified.

CHAPTER 4

SURVIVAL OF WHITE-TAILED DEER NEONATES IN SOUTHWEST MINNESOTA

INTRODUCTION

Determining causes of mortality and survival rates of white-tailed deer neonates (<1 month) is important for effective deer management and population modeling (Schulz 1982, Huegel et al. 1985a, Ballard et al. 1999). Many factors can contribute to vulnerability of white-tailed deer neonates to mortality including date of parturition (Whittaker and Lindzey 1999), maternal age (Ozoga and Verme 1986), dam-neonate behavior (White et al. 1972, Ozoga et al. 1982) habitat quality (Nelson and Woolf 1987), and predator density (Beasom 1974). Common causes of neonate mortality are predation, disease, and emaciation (Schulz 1982). Of these causes, several studies have shown predation to be the primary cause (Cook et al. 1971, Hamlin et al. 1984, Messier et al. 1986, Benzon 1998).

Although it may not be possible to eliminate or reduce the major factors affecting neonate survival, knowledge of these factors is necessary to advance understanding of deer herd dynamics and to improve predictive management strategies. Therefore, the objectives were to determine survival and cause-specific mortality rates of white-tailed deer neonates in an intensively cultivated region of southwest Minnesota. As a pilot study, we attempted to capture and radiocollar coyotes with the objective of estimating predator density and determining predator movement in the neonate study area.

METHODS

Use of net-guns deployed from helicopters and other capture methods were not appropriate for the capture of white-tailed deer neonates. Because of the neonate's passive behavior, cryptic coloration, inactivity, and fragility during the first two weeks of life, capture by hand was necessary (Downing and McGinnes 1969, Nelson and Woolf 1987). To obtain accurate survival and cause-specific mortality information on neonates from birth, the goal of the study was to capture and radiocollar neonates as soon as possible after parturition without disturbing the dam-neonate bond (White et al. 1972).

Neonate white-tailed deer were located using ground and vehicle searches during daylight and night hours in Lincoln and Pipestone counties, Minnesota (Fig. 8). Searches were conducted in areas where females exhibited postpartum behavioral changes (Huegel et al. 1985b). Ground searches were conducted by arranging crewmembers in an evenly spaced linear format and walking areas with high quality fawning habitat. Furthermore, in areas with a well-established road network, vehicle searches as described by Downing and McGinnes (1969) were conducted. After a neonate was observed, a quick and noisy approach was used to cause the female to flush if present, and the neonate to elicit the "drop" response (Nelson and Woolf 1987).

Captured neonates were sexed, aged, and weighed. Age of neonate was determined by measuring the distance from the hairline (outline of hair just above the hoof) to the ridged growth line on the abaxial wall of a front hoof (Haugen and Speake 1958, Fig. 14). Sams et al. (1996) examined eight morphometric measures and noted that hoof growth provided the most reliable and accurate aging model and was least affected by gender and maternal nutrition. Neonates were placed in a 4.8 mm-mesh drawstring sac and weighed to the nearest ounce using a digital hanging scale (Extech Instruments, Melrose, Massachusetts).

Neonates were fitted with expandable breakaway radiocollars (Telonics Inc., Mesa, Arizona) equipped with mortality sensors that activated after the collar had remained still for 4 hours. To minimize foreign scent, radiocollars were stored two weeks prior to capture in plastic bags filled with vegetation commonly found in fawning habitat. In addition, to reduce the chance of human scent transferred to handled neonates, gloves were worn by all personnel participating in neonate capture procedures. Capture location was recorded using a Global Positioning System (GPS) and total processing time was recorded.

Status of collared neonates was determined daily until approximately 9 weeks post-capture. After 9 weeks, neonates were monitored 2-3 times per week. A period of 9 weeks was selected because the first two months of life have been reported to be the “critical period” in which neonates are most vulnerable to mortality (Cook et al. 1971, Nelson and Woolf 1987). A vehicle-mounted radiotelemetry antenna system (Brinkman et al. 2001), and hand-held Yagi antennas were used for daily monitoring. Cause of death was determined from field necropsy and ancillary evidence at the kill site (White et al. 1987). If cause of death could not be determined in the field, carcasses were transported to the SDSU ADRDL for further investigation.

Survival rates were calculated using the Kaplan-Meier procedure (Kaplan and Meier 1958) modified for a staggered entry design (Pollock et al 1989). Survival rates were calculated monthly from June through August. Neonates were censored from analysis when mortality was capture-related or collars fell off neonates. Survival rates were compared between years, sex, and months using Program CONTRAST (Hines and

Sauer 1989); alpha was set at $P \leq 0.05$. A Bonferroni correction factor was used to maintain alpha when multiple Chi-squared and *t*-tests were performed.

To capture coyotes, breakaway neck snares (Phillips et al. 1990) and padded leg-hold traps (Olsen et al. 1986) were randomly placed along trails from April 2001 through June 2002 in Lincoln and Pipestone counties, Minnesota (Fig. 8). Snares were equipped with a "stop" to prevent killing coyotes and avoid capturing non-target species (e.g., skunk [*Mephitis mephitis*], raccoon [*Procyon lotor*]). Traps were checked 1-2 times daily. In addition to our efforts, a professional trapper was contracted to assist with coyote capture using similar methods. Captured coyotes were sexed, aged (pup or adult), inspected for ectoparasites and general physical condition, and fitted with a radiocollar (Advanced Telemetry System, Isanti, Minnesota).

RESULTS

A total of 39 (21 in 2001, 18 in 2002 [Table 9]) white-tailed deer neonates was captured and radiocollared in Lincoln and Pipestone counties, Minnesota (Fig. 8; Table 9, Appendix D, E). Neonates (17 male, 22 female) were captured between 22 May and 11 June. Eight neonates (20.5%) required a chase before capture, and several were able to elude capture. Of 31 (79.5%) neonates that remained still when approached, 15 (48.4%) were completely passive during handling. Four females (18.2%) and four males (23.5%) required a chase, and 68.2% of females and 58.8% of males struggled during capture. Average age at capture was 4.8 days (n = 34, SE = 0.6), and mean handling time was 3.4 minutes (n = 39, SE = 0.3; Table 9). Mean date of birth was 28 May (29 May in 2001, 27 May in 2002) based on estimated age at capture.

A total of 19 neonates was captured using daylight-ground searches, and 20 using vehicle searches (8 daylight, 12 night). A total of 107 search-hours (39 in 2001, 68 in 2002) and 469 man-hours (275 in 2001, 194 in 2002) were required to capture 39 neonates. An average of 2.7 search-hours (1.9 in 2001, 3.8 in 2002) and 12.0 man-hours (13.1 in 2001, 10.8 in 2002) were required per neonate captured. An average of 3.0 vehicle-search-hours (6.0 man-hours), and 2.4 ground-search-hours (19.3 man-hours) were required per neonate captured.

A total of eight mortalities occurred during 2001-02 (Appendix F, Table 10). Four neonates (66.7%) were killed by predators (Fig. 15). One neonate died from collision with a vehicle (16.7%), and another from disease (16.7%). According to SDSU ADRDL, the neonate died from enteritis. Supporting evidence strongly suggests that coccidia (*Eimeria* spp.) and coronavirus (*Coronaviridae*) were the disease causing organisms.

Two neonate mortalities (1 female in 2001, 1 male in 2002) may have been capture-related. Necropsies conducted at SDSU indicated that both neonates died of starvation. Both struggled during handling and were located dead within 3 days of capture <50 m from capture locations with no evidence of physical harm. It was suspected that these neonates were abandoned by females. Schulz (1982) suggested that if a female were to abandon her fawn due to human contact, the fawn would die 24-72 hours later because of high metabolic demands of the growing neonate. Until a neonate reaches 2 weeks of age, it is completely dependent on the dam’s milk. At approximately 2-3 weeks of age, the neonate’s rumen takes on adult proportions, and the animal is able to begin consuming vegetation (Gauthier and Barrette 1985). Because it was undetermined if the neonates were abandoned or died naturally, and it was less than one week post capture, they were censored from the study. During 2001, an additional three neonates were censored during 2001 because radiocollars fell off or broke-away from neonates.

During 2001, neonate survival rate after 1-month post-capture was 1.0 (n = 21) and 0.95 (n = 18) after 3 months of monitoring (Table 11). In 2002, survival rate was 0.78 (n = 18) after 1-month post-capture and 0.72 (n = 13) after 3 months of monitoring. Pooled survival rate was 0.84 (n = 39) for June-August 2001-02 (Table 11). Although comparisons of survival rates between months was similar (df = 2, χ^2 = 1.972, P = 0.373), most mortalities (n = 4) occurred during the first month, with an estimated June survival of 89.8%. July and August survival was 96.8% and 96.9%, respectively. Survival was similar (df = 1, χ^2 = 0.302, P = 0.583) between females (0.81) compared to males (0.88; Table 12).

A total of 1,350 trap nights (1 trap set for 24 hours) was employed to trap coyotes during this study. Trapping efforts in 2001 (1000 trap nights) went unsuccessful with one coyote being trapped in 2002 (350 trap nights). Based on personal communications with local and state trappers, low coyote density may be due to an outbreak of sarcoptic mange (*Sarcoptes scabiei*) that occurred in and around the study site during the late 1990s.

The coyote that was trapped and radiocollared was a male juvenile in good health. The juvenile was completely passive during handling and remained still after released from the trap. The coyote died one week later; death was capture related. The foot caught in the padded trap was chewed on extensively and became infected. However, at capture the foot was swollen, but did not appear to have any major damage (e.g., fractures, cuts).

DISCUSSION

Identifying the species responsible for the predator kills was difficult due to the lack of evidence at the neonate kill site. In three out of the four predator kills, only hair and blood were located near the location of the radiocollar. Bite marks were present on all four radiocollars. Scraps of deer hide and digestive tract accompanied one radiocollar, but the carcass was absence. We identified two of the predator moralities as coyote kills. This decision was based on sign (e.g., tracks, scat) near where the collar was located. Furthermore, the only coyote trapped and radiocollared during the study was captured in the same section of land where the two suspected coyote kills occurred. We were unable to identify the predators responsible for the other two kills.

All predator mortalities occurred >10 days postpartum. This is likely attributed to increased activity of the neonate, particularly in the absence of the dam. Neonates <2 weeks old were well protected by relatively dense ground cover, cryptic coloration, and inactivity. As the neonate ages, it becomes more observable and susceptible to predation (Nelson and Woolf 1987). Benzon (1998) suggested that higher mortality among male neonates in the Black Hills of South Dakota was due to behavior. Males were more likely to run when approached by capturers, whereas females remained passive. Thus, Benzon's (1998) hypothesis was that when a predator was near, a young male neonate would run and be caught instead of remaining still, as females did, and allowing the predator to pass. In southwest Minnesota, the oldest fawn killed by predation was approximately 8 weeks of age (Appendix F). Nelson and Woolf (1987) reported that neonates >8 weeks old were generally too swift to be caught by canids.

Pooled (2001-02) white-tailed deer neonate mortality (16%) in southwest Minnesota was lower than reported elsewhere in the Midwest Agricultural Region; 21% mortality in south-central Iowa (Huegel et al. 1985a), 30% mortality on a wildlife refuge in southern Illinois (Nelson and Woolf 1987), and 33% in central Missouri (Bryan 1980). Furthermore, heavy neonate losses have been reported in Texas (72%, Cook et al. 1971), Black Hills of South Dakota (40%, Benzon 1998), Colorado (66%, Whittaker and Lindzey 1999) and New Brunswick (53%, Ballard et al. 1999). Similar to this study, Schulz (1982) reported a 15% neonate loss preceding hunting season on a deer refuge in southeast Minnesota.

Grund (2001) noted that neonate survival may be related to winter severity, with survival decreasing with increasing winter severity. Although neither winter during this study was severe relative to the last 30 years (1971-2000; Midwest Regional Climate Center 2002), neonate survival did not decrease with an increased DWSI (Fig. 13; DWSI discussed in detail in Ch. 5). Neonate survival was higher in 2001 than in 2002, and DWSI in 2000-01 was approximately twice that of the DWSI in 2001-02 (Fig. 13). In fact, 2001 summer neonate survival (95%) in southwest Minnesota was one of the highest survival rates reported for free-ranging white-tailed deer. During the first 30 days postpartum, the time period when most neonate mortalities have been reported (Cook et al. 1971, Schultz 1982, Huegel et al. 1985a, Ballard et al. 1999), 2001 survival was 100%. Hansen et al. (1997) reported 100% survival between birth and 4 months for 17 marked neonates on an agricultural area in east central Illinois, and McGinnes and Downing (1969) reported 92% neonate survival, for a confined deer herd in Virginia.

Several studies have shown predation to be the primary cause of mortality for neonates (Cook et al. 1971, Hamlin et al. 1984, Messier et al. 1986, Nelson and Woolf 1987, Benzon 1998, Whittaker and Lindzey 1999), and overall losses are the highest when a predator, such as the coyote, is present (White et al. 1972, Ballard et al. 1999). Furthermore, local fluctuations in neonate survival rates have been attributed to changes in predator density (Beasom 1974, Stout 1982). Using our trapping efforts as an indicator of predator numbers, high neonate survival (84%) was likely associated with low predator density in the study area.

High neonate survival also may be associated with nutritional condition of females in southwest Minnesota. Using chest girth as an index (Ch. 3), adult does captured at the Lake Benton study site were in excellent condition. In intensive agricultural areas, does are maintained on a high nutritional plane because of access to a nearly unlimited and nutritious diet (Gladfelter 1984, Nixon et al. 1991). Even during winter months, deer can maintain a high quality diet on abundant waste grains left in crop fields after harvest (Warner et al. 1989). In a captive deer study in Michigan, Verme (1963) reported that mean birth weight of neonates of female deer maintained on a highly nutritious diet was 1.6 kg (86%) greater than young born to malnourished does.

Furthermore, newborn neonates that died during Verme's (1963) study were an average of 0.9 kg (31%) lighter at birth than those that survived.

In southwest Minnesota >80% of the land is cultivated (Ch. 2), and crops (e.g., corn, soybeans, oats, wheat) begin to emerge during early June (Minnesota Agricultural Statistics Service 2002). Hence, <20% of the land provides adequate cover for fawning, which occurs in late May and early June. Habitat available for fawning is composed of small patches of grassland and tree groves. Tree groves in the Lake Benton study site were primarily shelterbelts and abandoned farmyards with dense ground vegetation consisting mainly of smooth brome. Huegel et al. (1985a) and Benzon (1998) reported that regional differences in neonate survival may be largely influenced by vegetation structure at neonate bed sites. Vegetative cover is particularly important during the neonate's first month of life when it largely relies on cryptic coloration and inactive behavior to avoid being observed by predators (Nelson and Woolf 1987). With predators relying primarily on visual cues (Wells and Lehner 1978), increased ground cover would decrease a neonate's risk of predation. Although the amount of suitable fawning habitat is limited in southwest Minnesota, what is available is high quality and may be a contributing factor to the high survival rates observed.

CHAPTER 5

MOVEMENT OF FEMALE WHITE-TAILED DEER IN SOUTHWEST MINNESOTA

INTRODUCTION

In the northern part of their range, white-tailed deer are considered a migratory species (Marchinton and Hirth 1984, Demarais et al. 2000). Research has indicated that the onset of cold temperatures and snow depth exert the greatest influence on seasonal movement from summer to winter home range (Verme 1968, Ozoga and Gysel 1972, Verme 1973, Blouch 1984, Nelson 1995). During mild winters with below average snowfall, deer may occupy the same range year round or only briefly visit a winter range (Drolet 1976, Blouch 1984, Nelson 1995). White-tailed deer exhibit high site fidelity, and have been reported to move through suitable habitat en route to previous seasonal range (Tierson et al. 1985). Fawns and yearlings may disperse each year, moving from their original home range and establishing a permanent range elsewhere (Nixon et al. 1991, Nelson 1993). Amount of dispersal occurring between neighboring deer populations determines emigration and immigration rates, and may represent a significant exchange of individuals across areas (Rosenberry et al. 1999), which is important to management of PAs.

Movement of white-tailed deer has been well documented in the Forest Zone of Minnesota (Rongstad and Tester 1969, Kohn and Mooty 1971, Hoskinson and Mech 1976, Moen 1976, Mooty et al. 1987, Nelson 1993, 1995, DelGiudice 2000). However, literature is scarce for the Farmland Zone of Minnesota. Schulz (1982) determined newborn fawn home ranges in a Wildlife Management Area in southeast Minnesota, and Simon (1986) determined annual movements of fawn (≥6 months old) and adult (>1 year old) deer in the same area. No direct information related to movement of white-tailed deer exists in intensive agricultural areas of the Farmland Zone. Therefore, the objectives of this study were to determine seasonal movement (i.e., migration, dispersal) and home ranges of white-tailed deer in southwest Minnesota.

METHODS

Female white-tailed deer were captured and radiocollared at winter deer concentrations near the cities of Lake Benton, Walnut Grove, and Redwood Falls (Fig. 4; see Ch. 3 for capture and handling methods). Individual, radiocollared fawn (~8 months at capture) and adult (>1 year at capture) white-tailed deer were monitored for mortality 2-3 times per week and located by ground triangulation twice per week. Azimuths (3-5) were estimated from established telemetry stations using a vehicle mounted "null-peak" antenna system (Brinkman et al. 2002) connected to an electronic compass (C100 Compass Engine, KVH Industries, Inc., Middletown, RI; Cox et al. 2002). If deer could not be located from the ground, a fixed-wing aircraft was used. Locations of visually observed and undisturbed individuals were assigned Universal Transverse Mercator (UTM) coordinates. To calculate deer locations, azimuths were entered into the computer program Locate II (Nams 2001), and plotted on USGS 3-meter Digital Orthophoto Quadrangles using the software program ArcView (ESRI, Redlands, CA). Fixed kernel method with least-squares cross-validation to determine smoothing parameter was used to calculate home ranges (Seaman et al. 1999). Kernel estimators are nonparametric, and are not based on an assumption the data conform to specified distribution parameters (Seaman et al. 1999).

Seasonal migration was calculated by measuring the distance between center points of seasonal home ranges. If overlap existed between seasonal home ranges, migration did not occurr (Nicholson et al. 1997). Seasonal movement was considered dispersal if deer moved from original home ranges and established permanent home ranges elsewhere (Marchinton and Hirth 1984). Deer were considered obligate migrators (Sabine et al. 2002) if they migrated annually to winter range and remained there until spring before returning to summer range. Deer were considered conditional migrators (Nelson 1995) if they failed to migrate to a previous winter range, only briefly (<1 month) visited winter range, or made several migrations between seasonal ranges during a single winter. Deer were considered residents (VerCauteren and Hygnstrom 1998) if they remained non-migratory a minimum of three consecutive migratory periods. Only individual deer that were monitored through three consecutive migratory periods were assigned a migration strategy (i.e., obligate, conditional, permanent residents). Seasonal movement from winter to summer range was classified as spring migration, and movement from summer to winter range was classified as fall migration.

Statistical analyses were performed using SYSTAT (Wilkinson 1990), and differences in movements between or among groups of deer were compared with *t*-tests or Chi-squared tests. Alpha was set at $P \leq 0.05$, and a Bonferroni correction factor was used to maintain the experiment-wide error rate when multiple Chi-squared and *t*-tests were performed (Neu et al. 1974).

RESULTS

Seventy-seven deer (61 adult, 16 fawn) were captured and radiocollared during January 2001 (*n* = 58; Table 2) and 2002 (*n* = 19; Table 3) at three study sites in southwest Minnesota (Fig. 4). Thirty-one deer were captured at the Lake Benton study site, 19 at Walnut Grove, and 27 at Redwood Falls. Deer were monitored from January 2001-August 2002. A total of 6,867 deer locations was collected with a mean 95% error ellipse of 3.8 ha. A total of 149 seasonal movements was documented during three migratory periods; spring 2001, fall 2001, and spring 2002 (Appendix G, H). Thirty-nine, three, and 26 individual deer were monitored through 3, 2, and 1 migratory period(s), respectively. A total of 130 individual home ranges were calculated during 4 seasonal range periods; winter 2000-01, summer 2001, winter 2001-02, and summer 2002 (Appendix G, H). One, 27, 11, and 23 home ranges were calculated for individual deer during 4, 3, 2, and 1 seasonal range period(s), respectively.

SPRING MOVEMENT 2001

During spring 2001, 40 deer (75.5%) migrated a mean distance of 8.8 km (SE = 1.1; range = 29.2 km; Table 13). Nine individuals (17.0%) did not migrate and used at least part of their winter range as summer range. Four deer (7.5%) dispersed (2 fawn, 2 adult) and established permanent ranges elsewhere (Fig. 16). Mean dispersal distance was 71.3 km (SE = 45.1) and varied from 16 to 205 km. Of the 44 deer that migrated or dispersed from winter ranges, median departure date was 8 April and varied from 10 March to 25 May.

Mean migration distance in Lake Benton (Fig. 17), Walnut Grove (Fig. 18), and Redwood Falls (Fig. 19) study sites was 8.5 km (SE = 1.2; n = 16), 7.8 km (SE = 2.2; n = 14), and 11.6 km (SE = 2.4; n = 12), respectively (Table 13). Lake Benton had the highest percentage (88.9%) of migrating deer in spring 2001, followed by Walnut Grove (87.5%), and Redwood Falls (70.6%). Two dispersals occurred at Redwood Falls, one at Walnut Grove, and one at Lake Benton (Fig. 15), with deer leaving original home range and establishing new home ranges elsewhere.

FALL MOVEMENT 2001

During fall 2001, 23 (56.1%) deer migrated a mean distance of 11.2 km (SE = 1.7; range = 28.8 km; Table 13). Of the 40 deer that migrated during spring 2001, 32 were monitored during fall 2001. Twenty-one (65.6%) of these deer migrated a mean distance of 10.6 km (SE = 1.5) to their previous winter range. Of the 4 dispersals that occurred during spring 2001, two were monitored during fall 2001, and migrated a mean distance of 17.9 km (SE = 12.5) to a new winter home range. Eleven (34.4%) did not migrate, and these remained on summer range through winter 2001-2. Median departure date from summer home range for migratory individuals was 28 November (n = 21) and ranged from 31 October to 22 December. Timing of migration of 2 individuals was unidentifiable. In spring 2001, all 9 non-migratory individuals in spring 2001 remained non-migratory during fall migration 2001.

Mean fall 2001 migration distances in Lake Benton, Walnut Grove, and Redwood Falls study sites were 9.3 km (SE = 1.0; n = 10), 13.6 km (SE = 4.0; n = 8), and 11.2 km

(SE = 4.0; *n* = 5), respectively (Table 13). Lake Benton had the highest percentage of fall migraters (62.5%), followed by Walnut Grove (58.3%), and Redwood Falls (45.5%).

SPRING MOVMENT 2002

During spring 2002, 32 deer (58.2%) migrated a mean distance of 11.4 km (SE = 1.2; Table 13). Because deer captured during winter 2001-02 were not monitored during 2002 fall migration, spring 2002 dispersal was unknown. Of the 23 deer that did not migrate, 15 were individuals that did not migrate from summer ranges during fall 2001, four were deer captured during winter 2001-02, and four were deer that had migrated during previous seasons. Nearly all individuals (85.7%) who did not migrate the previous spring (2001), and were monitored during spring 2002 (*n* = 7), remained non-migratory. Median date of winter range departure spring 2002 was 18 April (*n* = 27) and varied from 31 March – 30 May.

Mean spring 2002 migration distances in Lake Benton, Walnut Grove, and Redwood Falls study sites were 9.4 km (SE = 1.2; *n* = 18), 13.8 km (SE = 4.8; *n* = 5), and 11.2 km (SE = 2.5; *n* = 8), respectively (Table 13). Lake Benton had the highest (df = 2, χ^2 = 9.527, *P* = 0.009) spring migration (82.6%), followed by Walnut Grove (41.7%), and Redwood Falls (40.0%).

HOME RANGE

Seasonal home ranges of individual deer were calculated using a minimum of 25 and a mean of 37.3 (SE = 0.8, *n* = 130) locations. Deer locations were estimated during the last portion of winter 2000-01, and two individuals were located frequently enough to calculate home ranges. Therefore, winter 2000-01 was pooled with winter 2001-02 in analyses. Summer 2001 home ranges did not differ (df = 1, $t = 1.553$; $P = 0.124$) from summer 2002, and also were pooled in analyses.

Mean 95% and 50% winter home range use areas were 5.2 km^2 (range = 18.4 km^2; $n = 37$), and 0.8 km^2 (range = 3.3 km^2; $n = 37$), respectively (Table 14), and did not differ among study sites (df = 2, $\chi^2 = 1.995$, $P = 0.369$). Deer at Lake Benton had a mean 95% winter home range use area of 6.9 km^2 (SE = 2.1; $n = 11$), followed by Walnut Grove ($\bar{x} = 5.7$ km^2; SE = 1.0; $n = 12$), and Redwood Falls ($\bar{x} = 3.4$ km^2; SE = 0.7; $n = 14$; Table 14).

During summer 2001 and 2002, mean 95% and 50% home range use area was 2.3 km^2 (range = 12.4 km^2; $n = 93$) and 0.3 km^2 (range = 1.6 km^2; $n = 93$), respectively (Table 14), and did not differ between sites (df = 2, $\chi^2 = 5.246$, $P = 0.073$). Deer at Lake Benton had 95% summer home range use area mean of 2.6 km^2 (SE = 0.4; $n = 36$), followed by 2.2 km^2 (SE = 0.3; $n = 26$) at Walnut Grove, and 1.8 km^2 (SE = 0.2; $n = 31$) at Redwood Falls (Table 14).

DISCUSSION

SEASONAL MIGRATION

Mean migration (10.1 km; Table 5) distance in southwest Minnesota was slightly lower than reported in northern white-tailed deer studies (23.2 km, Sparrowe and Springer 1970; 13.8 km, Verme 1973; 20.7 km, Hoskinson and Mech 1976; 11.0 km, Simon 1986; 13.0 km, Nixon et al. 1991; 15.7 km, Griffin et al. 1994; 6.8-20.2, Sabine et al. 2002). Mixed seasonal migration strategies have been well documented among white-tailed deer populations (Rongstad and Tester 1969, Sparrowe and Springer 1970, Drolet 1976, Blouch 1984, Nelson 1995, VerCauteren and Hygnstrom 1998, Sabine et al. 2002). Results from this study support these earlier findings. In southwest Minnesota, female deer exhibited a mixture of migration behavior strategies consisting of obligate migrators, conditional migrators, and permanent residents. Of 39 deer that were continuously monitored through three migration periods (i.e., spring 2001, fall 2001, spring 2002), 15 (38.5%) were obligate migrators, 18 (46.2%) conditional migrators, 5 (12.8%) permanent residents, and one migration strategy could not be determined due to insufficient data.

Among northern white-tailed deer, fluctuations in temperature and snow depth exert the strongest effects on seasonal movement (Verme 1968, Ozoga and Gysel 1972, Verme 1973, Blouch 1984, Beier and McCullough 1990, Nelson 1995). In addition, Nicholson et al. (1997) reported that mule deer (*Odocoileus hemionus*) can maintain a mixed migration strategy in areas with extremely variable precipitation and snow cover. To determine if effects of temperature and snow depth apply to deer populations in southwest Minnesota, a DWSI was derived from the literature and analyzed with movement data from this study.

The *effective critical temperature* for an average size adult female deer has been calculated at -7 C° (DelGiudice 2000). At or below this temperature threshold, heat losses may exceed energy expendature for standard metabolism and activity, and additional heat is generated to maintain homeothermy (McDonald et al 1973). Also, Tierson et al. (1985) and Nelson (1995) reported that temperatures of <-7 C° can initiate fall migration. Kelsall (1969) noted that deer are considerably restricted in movement when snow exceeds depths of 40 cm (about 20 cm less than deer chest height). Also, such depths have been reported to initiate seasonal migration to winter range. Drolet (1976) estimated the threshold for beginning migration to be 30.4 cm, and Nelson and Mech (1981) reported 35-40 cm in northern Minnesota. Sabine et al. (2002) reported that peak migration coincided with accumulation of 40 cm of snow in all 4 years of a New Brunswick study. Using this information, DWSI for this study was calculated in each study site by accumulating 1 point for each day mean ambient temperature was ≤-7º C, and an additional point for each day snow depth was ≥35 cm during the months November-March (National Climatic Data Center 2002, Climatology Working Group 2003). October and April were not included in the DWSI because no days were reported with temperatures below -7 Cº, and the snow depth never was ≥35 cm. The DWSI developed for this study was designed to be white-tailed deer specific.

Average DWSI during winter 2000-01 (138.7; Fig. 11) was greater than winter 2001-02 (50.7; Fig. 12). Drolet (1976), Blouch (1984), and Nelson (1995) reported that during mild winters with below average snowfall, deer may occupy the same range year round or become conditional migrators. Lower DWSI in all study sites during winter 2001-02, relative to DWSI during 2000-01 (Fig. 13), may explain why 34.4% of individuals did not return to winter range during fall 2001, and exhibited conditional migration. There were conditional migrating deer that returned to winter range in 2001-02, but only for a brief period, and others made several trips between summer and winter range. For instance, adult female deer 611 (D611) at Lake Benton, made four migrations of approximately 12 km between summer and winter range during winter

2001-02. Deer 611 departed summer range on 28 November 2001, returned on 20 February, departed again on 27 March for winter range, and returned to summer range and remained there a few days later. During spring 2002, adult D689 departed from winter range on 2 May, traveling 22.4 km to summer range. Deer 689 was located on 7 and 9 May on summer range. On 10 May, D689 traveled 22.4 km back to winter range, where she remained until 31 May. During the first week of June, D689 made her final trip back to summer range where she remained until fall. Explanations as to why a variation in the prevalence of conditional migration existed among deer in the same area were speculative. However, Nelson (1995) suggested that differences in hunting mortality on summer range, and lower population size and density may influence migration among deer in adjacent wintering areas. Furthermore, Sabine et al. (2002) suggested that distribution of the behavior among individual deer was influenced by migration distance.

Temperature and snow depth influenced seasonal migration in southwest Minnesota. Fall migration by most deer in southwest Minnesota coincided with accumulation of snow and decreasing temperatures. During fall 2001, a winter storm occurring 26-28 November initiated fall migration for 52% of 21 deer with known summer range departure dates (Fig. 20). Migration was in response to snow depths of 36 cm at the Lake Benton and Walnut Grove study sites, and 16 cm at Redwood Falls. Mean ambient daily temperatures during this migration were -4 C° to -6 C°, and were the lowest recorded so far that fall.

Crop harvest had minimal impacts on fall migration. According to the Minnesota Agricultural Statistics Service (2002), the 1996-2000 average harvest completion date for 90% of the corn and soybeans was 3 November and 16 October, respectively, whereas median date of fall migration was not until 28 November (n = 21) and ranged from 31 October – 22 December. In addition, the planting of crops did not have an effect on spring migration. Median date of winter range departure was 8 April in 2001 (n = 44) and 18 April in 2002 (n = 27), whereas the 1996-2000 average planting completion date for 90% of the corn and soybeans was 30 May and 4 June, respectively (Minnesota Agricultural Statistics Service 2002).

Similar to fall migration in southwest Minnesota, temperature and snow depth influenced spring migration. However, movement was less abrupt compared to fall migration (Figs. 21, 22). During winter 2000-2001, Lake Benton and Walnut Grove had higher (df = 2, χ^2 = 100.04, P < 0.0001) DWSIs than Redwood Falls (Fig. 11). Thus, spring migration influences were analyzed separately. Between 28-31 March 2001, nine (29%) deer at Lake Benton and Walnut Grove departed winter range (Fig. 21). On March 27, prior to migration, temperatures increased and stayed above -9 C° and snow depths declined below 30 cm for the first time that month. The second spring migration at Lake Benton and Walnut Grove began between 4-7 April, when 8 deer (26%) responded to a week of temperatures ≥0 C°. In addition, snow depths were 28 cm on 31 March and had melted by 6 April. Factors influencing 2001 spring migration at Redwood Falls were less apparent (Fig. 21). Departure from winter range occurred between 10 March - 18 May with two individuals migrating in response to similar temperatures and snow depths. Compared to Walnut Grove and Lake Benton, Redwood Falls experienced milder and more gradual changes in weather conditions with few days where temperatures and snow depths reached migration thresholds.

Winter 2001-02 was much milder across all study sites compared to winter 2000-01 (Fig. 13). In 2002, the first group of deer to begin migration departed between 2-7 April, when 10 (37%) responded to a 10-15 C° rise in mean ambient temperature across all study sites; temperatures increased from –6 C° on 3 April to 4 C° – 9 C° on 7 April (Figure 22). Snow depths were minimal (5 cm) at this time and likely played less of a role in initiating migration. The second group to migrate simultaneously departed between 1-3 May. No sudden shift in temperature coincided with this migration, nor was there any snow accumulation at this time. A minor snow fall (2-5 cm) occurred on 28 April, but had melted the following day.

Late season migrators are likely less influenced by low ambient temperatures and snow depths. These deer remain on winter range well into spring thaw, after snow has melted and temperatures have risen and remained above 0 Cº. Migration among these animals was initiated by other variables. Potential late season spring migration stimuli include plant phenology (Nixon et al. 1991) and pre-parturition movement (Ozoga et al. 1982, Simon 1986). Hypothetically, because late season migrators were less sensitive to winter severity, these deer were more likely to be obligate rather than conditional migrators. Data from this study added some support to this hypothesis in that median spring 2001 departure date for obligate migrators (9 April, n = 15) was five days after median departure date (4 April, n = 16) of conditional migrators in spring 2001. During spring 2002, median departure date of obligate migrators (24 April, n = 10) was nearly two weeks after median departure date (12 April, n = 6) for conditional migrators.

Because deer were not monitored daily, number of days between departure and arrival on ranges was unknown. However, there was minimal meandering between seasonal ranges, and the majority of monitored females completed migrations, regardless of distance, in <1 week. Nixon et al. (1991) noted rapid migration in Illinois with deer settling on summer ranges within 10-12 days of initial movement. In northeast Minnesota, migrations from winter yards were completed in <2 weeks (Nelson and Mech 1981).

DISPERSAL

White-tailed deer within the Midwest Agricultural Region are unique because annual female dispersal is common (Gladfelter 1984). Fifty percent of female fawns, and 21% of yearling females dispersed each spring in Illinois (Nixon et al. 1991). Similarly, Nelson (1993) noted 20% yearling female dispersal in northeastern Minnesota. During 2001, 17% of fawns, and 5% of adults exhibited spring dispersal in southwest Minnesota. Whether these adults were yearlings was unknown. Dispersal distance varied significantly (n = 4, range = 189 km). Furthermore, dispersing deer had strikingly different winter range departure behavior than migrating individuals. All dispersers migrated to pre-dispersal home ranges before dispersing to new permanent ranges. For example, adult deer D591 departed from the Redwood Falls winter range on 12 April. We were unable to receive a signal until 3 June, when D591 was located 22.0 km southwest of its previous location, and remained on this temporary range until 19 June when it dispersed. On 2 December 2001, D591 was located near the town of Oldham, South Dakota, an approximate straight-line distance of 205 km from previous winter range (Fig. 16), which is the longest female dispersal distance reported for white-tailed deer. Kernohan et al. (1994) reported a dispersal distance of 213 km for a yearling male in northeastern South Dakota, and Sparrow and Springer (1970) reported a 161-km dispersal in eastern South Dakota. Nelson (1993) reported a 168 km dispersal in northeastern Minnesota. Dispersing adult D372 at Lake Benton exhibited behavior similar to that of D591. Departing from winter range on 19 April, D372 was not relocated until 9 May, when it was located 6 km from its previous location. Deer 372 remained on this temporary range until 20 May, when it moved back to previous winter range for 5 days and then dispersed. Deer 372 was located on 24 July approximately 18.7 km south of winter range where she established a new permanent summer range. Also, dispersing fawns D782 and D862 established temporary ranges that were occupied for roughly a month before dispersing on 28 June and 3 June, respectively. All dispersers migrated to a new winter range during fall 2001.

Social pressures have been identified as the primary stimuli for dispersal (Marchinton and Hirth 1984). Near parturition, the dam often runs off her previous fawns, encouraging them to disperse (Downing and McGinnes 1969). We observed this behavior during night hours under spotlight, while conducting vehicle searches for white-tailed deer neonates in southwest Minnesota, spring 2002. Pregnant dams would “flail” when approached by year-old fawns, or would run fawns off by chasing and using a “foreleg kick”. The dam’s aggressive behavior towards the year-old fawns may explain the existence of the temporary range used by dispersing fawns D782 and D862. Because mean date of migration has been identified to occur among female deer before parturition, a window of time exists between the dam's arrival at her summer range and the time just before parturition when her previous fawns are forced to depart. In addition, dispersal behavior among fawns is almost unknown before 11 months of age (Nixon and Etter 2001). Hence, a 10-11 month-old fawn follows her mother to summer range, and remains for roughly a month (i.e., pre-dispersal range) until forced to depart prior to parturition. In intensive agricultural areas with limited available cover in the spring, fawns often travel long distances before finding suitable habitat not occupied by other females (Demarais et al. 2000; Nixon et al. 2001).

Explanations as to why adult females D372 and D591 dispersed are more complicated. Exact ages of D372 and D591 were unknown. However, it is possible that one or both were yearlings. If this were the case, it was possible that this was their initial pregnancy and they dispersed to seek solitude to fawn. Ozoga et al. (1982) suggested that "complete isolation is essential for proper mother-infant bond formation." In nutritient-rich landscapes (e.g., southwest Minnesota), competition among females for parturition sites may be more important than food competition, and white-tailed deer will forcefully defend fawning grounds (Nixon et al. 1991, 2001). Matriarch females defend the same fawning area annually (Ozoga et al. 1982). Because of the difficulty of establishing fawning grounds in highly fragmented, competitive agricultural environments with limited cover, D591 and D372 may have been forced to move a great distance before finding suitable habitat. Another explanation why D591 and D372 dispersed was that they may have been unsuccessful mothers. Ozoga et al. (1982) noted that unsuccessful mothers fail to exhibit any prolonged isolation or aggressive behavior. Without fawns, they lack the innate behavior to defend summer ranges. Barren females often revert to the social position of a fawn (Ozoga and Verme 1986, Nixon et al. 1991). Therefore, to avoid confrontation with territorial does rearing fawns, D591 and D372 may have dispersed.

HOME RANGE

In northern regions, snow depth, deer density, and low temperatures have the greatest influence on daily activity of white-tailed deer (Verme 1973, Tierson et al. 1985, Beier and McCullough 1990). In response to severe weather conditions, deer will minimize movement to conserve energy (Moen 1976, Parker et al. 1984). Hence, it is predicted that white-tailed deer will have smaller ranges in winter than in summer. In New York, female deer summer and winter home ranges averaged 2.21 km^2 and 1.32 km^2, respectively (Teirson et al. 1985). In northeastern Minnesota, Nelson and Mech (1981) noted mean summer and winter ranges of 0.83 km^2 and 0.44 km^2, respectively, and Mooty et al. (1987) reported mean summer and winter ranges of 0.69 km^2 and 0.43 km^2, respectively. In southwest Minnesota, mean winter home range (5.18 km^2, $n = 37$) was more than double mean summer home range (2.27 km^2, $n = 93$; Table 14). In southwest Minnesota and other intensively cultivated areas, condensed summer home ranges were likely due to unlimited cover, and nutritious food supplies throughout the landscape provided by farming activities. Furthermore, Nixon et al. (1991) and Ozoga et al. (1982) noted a reduction in daily movement by females during the pre and post-fawning period.

Home ranges of deer are extremely variable (Nicholson et al. 1997). Previous reports of home ranges of northern white-tailed deer include estimates of 1.61-4.80 km^2 (Rongstad and Tester 1969); 2.50 km^2 (Sparrowe and Springer 1970); 1.67-4.71 km^2 (Kohn and Mooty 1971); 0.48-4.10 km^2 (Hoskinson and Mech 1976); 0.48-4.10 km^2 (Hoskinson and Mech 1976); 0.28-1.40 km^2 (Simon 1986); 1.89-3.77 km^2 (Griffin et al. 1994); 1.70 km^2 (VerCauteren and Hygnstrom 1998); and 4.37 km^2 (Kernohan et al. 2002). In general, home range estimates should be interpreted with caution. Home range can vary with age and sex of the individual, habitat, and season (Demarais et al. 2000), and are likewise affected by human activities (e.g., agricultural activities). VerCauteren and Hygnstrom (1998) reported that deer in Nebraska shifted their range 174 m toward cornfields when corn development reached tasseling-silking stage, and home range shifted again after harvest 157 m, with mean size becoming 32% larger.

There were an insufficient number of locations to determine the approximate effects of crop harvest on seasonal home range of southwest Minnesota deer. However, impacts seemed minimal, and during crop harvest, radiocollared deer moved to nearby (<1 km) forest or grassland habitat they occupied on their summer range prior to crops reaching concealment height.

CHAPTER 6

MANAGEMENT IMPLICATIONS

To improve the "realism" of the simulated output of the farmland model, accurate empirical data are required (Grund 2001). Thus far, researchers in southwest Minnesota have used educated guesses, rather than empirical data specific to the region to evaluate the biological parameters that are entered into the model. No direct information was available on movement and mortality of white-tailed deer in intensively cultivated areas of farmland Minnesota. This study documented that adult female and neonate white-tailed deer populations have high survival and minimal vulnerability to death by natural causes in intensively cultivated areas (Ch. 3, 4). Human-related mortalities (i.e., hunting, vehicle collision) are the primary factors impacting deer in southwest Minnesota. Nutritious and abundant food supplies provided by farming activities set carrying capacity well beyond current deer population levels in agricultural areas (Hansen et al. 1997). Hence, keeping deer populations at levels tolerable to landowners, while providing maximum hunter opportunities are primary management objectives. Based on this research, annual reduction of deer numbers to meet population goals in southwest Minnesota was almost entirely dependant on hunter harvest.

Intensive farming practices amplify the effectiveness of using hunting as the primary tool for regulating deer numbers in southwest Minnesota. Crop harvest generally occurs before Minnesota's firearm hunting season. Therefore, deer in this highly fragmented agricultural landscape occupy small remaining patches of permanent cover leaving them vulnerable to hunters. Because of the scarce forest cover in southwest Minnesota (Ch. 2), hunters can effectively reduce deer numbers annually to achieve management population goals. Due to the extreme dependence on hunters to control deer numbers, special attention should be given to deer harvest data collection (e.g., number harvested, age, sex) to minimize uncertainties (Grund 2001).

Under some circumstances, deer herds may not be efficiently managed through the allocation of hunting permits. Nixon et al. (2001) suggested that thousands of private landowners with varying opinions on hunting have created a mosaic of refuge and non-refuge patches in central and northern Illinois. Hunting pressure is generally low on many private properties (Hansen et al. 1997), and land acquired by conservation organizations (e.g., The Nature Conservancy) and/or land set aside as a state/national park may not allow hunting. Deer herds unregulated by hunting can cause high levels of depredation, angering surrounding landowners and creating a dilemma for wildlife managers. In this particular case, allocation of special depredation permits may be necessary. Hansen et al. (1997) suggested that refuges in agricultural landscapes with more than 5% permanent cover may hinder deer management efforts. Southwest Minnesota has approximately 10% in permanent cover (Table 1), thus, special consideration should be given to PAs that contain refuges. For instance, landowners adjacent to refuges may be particularly vulnerable to depredation if deer herds are not adequately managed annually through harvest.

Although allocation of hunting permits and harvest regulates populations, managers need to consider effects of winter severity. DelGiudice (2002) noted that a severe winter (i.e., 1995-96) had “excessive” impacts on deer herds in northern Minnesota. Furthermore, Grund (2001) reported that survival rates were related to winter severity indices in central Minnesota. Because this study was conducted during a moderate winter (2000-01) and mild winter (2001-02) with few deer mortalities (Ch. 3), the direct influence of severe winter weather conditions on farmland deer survival was undetermined. Additional monitoring during a "harsh" winter is necessary to identify relationships between severe winters and mortality, and to evaluate variation between years.

Northern deer in agricultural regions have adapted to highly fragmented environments by dispersing and exhibiting seasonal migration. The farmland deer model does not incorporate deer movement information. In fact, the farmland deer population model assumes that emigration/immigration does not occur between PAs (DePerno et al. 1999). Although wildlife managers and research biologists know this assumption is incorrect, empirical data to determine amount of movement occurring across PA boundaries was lacking. Similarly, information on the frequency of seasonal migration routes crossing PA boundaries was unknown. In this study, radiocollared deer dispersed across and migrated between PAs. If dispersal and migration between PAs was equal was undetermined.

Although the influence of winter weather on survival of deer in southwest Minnesota was undetermined, a clear relationship was identified between movement and winter severity. Migration was influenced by snow depth and mean ambient temperature. For this study, mean distance migrated was 10.1 km (n = 95, SE = 0.7; Table 13) and many deer had summer home ranges in PAs different from winter ranges (Figs. 17-19). Therefore, migratory individuals harvested in one PA may potentially impact deer numbers in another PA. In this particular case, population estimates during the summer may not adequately represent deer numbers during winter. For example, during 2001, the majority of fall migration occurred in late November following a severe weather event (Ch. 5, Fig. 20). In 2001, the firearms hunting season occurred during the first two weekends of November. Therefore, during the 2001 deer season (when deer populations were actively managed), the majority of migrating deer were occupying summer range. If migration occurred before the hunting season, PA deer numbers and densities potentially could have changed. For example, suppose temperature and snow depth reached thresholds that initiate migration prior to the hunting season, deer would then occupy winter ranges. In this hypothetical situation, PAs containing large wintering yards could potentially have greater deer numbers, whereas PAs serving primarily as summer ranges would have lower deer numbers. The influence on deer harvest is speculative. However, the logical explanation for this scenario is that hunters in permit areas with higher deer densities would have higher success at harvesting deer. On the other hand, if wintering yards were located on refuge areas or private land with minimal or no hunting, then harvest rates and hunter opportunities would be reduced. Because southwest Minnesota deer migrate between PAs, and severe weather influenced migration (Ch. 5), it is recommended that researchers and wildlife managers consider timing of winter arrival and severity of winter weather when evaluating harvest data. Continued monitoring of the relationship between migration and weather variables (i.e., snow depth, temperature) may help support thresholds (i.e., -7 C°, snow depth = 35 cm) used to calculate the DWSI for farmland Minnesota. In addition, because timing of arrival of severe weather may initiate migration of deer across PA boundaries, population surveys are recommended during summer and winter months to obtain accurate and precise estimates of deer numbers in each PA. Also, seasonal population estimates may provide insight into immigration/emigration and dispersal rates.

Although, there was evidence of deer movements across PA borders, the majority of radiocollared female deer did not migrate across major highways, which supports the use of major roads as deer PA boundaries (Fig. 23). For instance, only 4% of migrating deer at Redwood Falls (n = 25) traveled across a major highway (Fig. 19), and less than 50% crossed highway systems at Lake Benton (Fig. 17) and Walnut Grove (Fig. 18). At all three sites, major highways were located <3 km from capture location.

During 2001, 17% of female fawns (~8 months at capture) and 5% of female adults (>1 year at capture) dispersed a mean distance of 71.33 km (SE = 45.07); dispersal and ranged from 16 to 205 km (Fig. 16). According to the farmland deer population model, the estimated number of deer in southwest Minnesota (24 permit areas, Fig. 3) during spring 2001 was 32,366 fawns (~10-11 months) and 21,284 adults (Erb et al., Minnesota Department of Natural Resources, unpublished data). If the assumption was made that 17% of fawns and 5% of adults uniformly dispersed across the study area, 6,566 deer could have potentially immigrated into and/or emigrated out of southwest Minnesota PAs in 2001. This value may actually be much greater, because only females were monitored and several studies have reported higher dispersal rates among males (Nelson and Mech 1984, Nixon et al. 1991, Nelson 1993, Rosenberry et al. 1999). Because dispersal was determined for only one spring migratory period, these estimates should be interpreted with caution, and additional research is necessary.

With dispersal potentially causing a significant exchange of individuals across PAs, incorporating predicted emigration and immigration into the deer model would improve management strategies. However, monitoring animals traveling over long distances and measuring movements from unknown locations is difficult (Rosenberry et al. 1999). For instance, in this study we were unable to determine the two longest dispersal distances (Fig. 16) using radiotelemetry alone. Because deer move between ranges with little meandering, we were unable to relocate D591 and D782 shortly after they dispersed. Attempts at locating these individuals from a fixed-wing aircraft were unsuccessful. Fortunately, a MN DNR Conservation Officer conducting a road survey observed and reported D782 at its new location, and D591 was reported by an archery hunter in South Dakota. Use of Global Positioning System (GPS) collars may remedy this problem in the future, but budgetary restraints limit their use. Therefore, it is recommended that deer monitoring be intensified during dispersal periods to minimize lost signals due to long distance movements.

After dispersal is determined, the challenge remains as to whether immigration equals emigration in southwest Minnesota PAs. Nixon et al. (1991) suggested that large numbers of previous years fawns alive in the pre-fawning population may be the major factor promoting high dispersal in Illinois. Using this hypothesis, Minnesota PAs with high percentages of 9-month-old fawns relative to adjacent PAs would experience greater emigration. Also, harvest data may provide cues to whether immigration or emigration is occurring. In a region where deer have access to a nearly unlimited and nutritient rich food supply (e.g., southwest Minnesota), social pressures have been identified as a reason for dispersal. Social pressure increases with deer density (Marchinton and Hirth 1984), and this relationship may be amplified in intensively cultivated areas with limited cover. Theoretically, PAs with high annual deer harvests would have fewer emigrations because habitat vacancies would be created and deer would be required to disperse shorter distances to find suitable habitat to establish new summer home ranges. In contrast, a PA with high harvest may experience greater levels of immigration, especially if adjacent PAs have high deer densities and low harvest rates. Furthermore, PAs with high rates of female deer harvest may have lower dispersal rates because of an increased percentage of orphaned fawns. Holzenbein and Marchinton (1992) noted that orphaned fawns were 76% less likely to disperse than those with does present that forced them to leave their natal range. Future research evaluating major factors (e.g., deer density, habitat changes) influencing dispersal timing and distance is recommended.

This study was designed to determine movement and mortality of white-tailed deer in a 24 PA area of southwest Minnesota. To meet this goal, study sites were carefully chosen to accurately represent the major land use/cover types throughout the southwest region (Ch. 2). Movement and mortality differences between study sites have been discussed (Ch. 3, 5). Also, information from this study may be applicable for other areas of Minnesota. These data may be extrapolated to white-tailed deer herds in other highly fragmented regions with intensive cultivation, limited permanent cover, high hunter density, high road density, low predator density, and large fluctuations in seasonal climate. These factors likely had the most significant influence on movement and mortality in southwest Minnesota. Nevertheless, to determine landscape level thresholds in southwest Minnesota, long-term data is crucial. High survival over a relatively short time period (20-month period) produced a small sample of mortalities (especially non-hunting) to evaluate and compare across PAs. Furthermore, additional seasonal monitoring is necessary to determine trends across years with varying winter severity. Although study sites were chosen to encompass maximum land cover variability, the southwest study area was relatively uniform (Table 1), which made it difficult to identify unique ecological components affecting white-tailed deer in southwest Minnesota. A landscape-level approach is necessary to understand long-term trends and effects of varying deer densities across farmland Minnesota.

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Table 1. Percentages of major land use/cover types of deer permit areas in southwest Minnesota (Minnesota Department of Natural Resources 2000).

Permit Area	Cultivated	Grassland/shrub	Forest	Water	Wetland
424	86.93	4.73	2.22	1.76	1.36
425	92.53	2.74	1.61	0.14	0.40
426	85.00	4.68	2.98	3.49	1.56
427	87.80	4.42	2.59	1.62	1.22
431	75.50	8.45	2.75	5.51	3.36
433	67.74	15.72	4.73	4.75	2.88
435[a]	**82.30**	**6.72**	**7.26**	**0.98**	**0.41**
440	85.85	3.54	6.77	0.76	0.34
442	92.37	1.91	3.05	0.73	0.49
443	81.01	4.27	9.17	1.28	0.27
446	79.88	13.08	2.84	0.56	0.95
447	90.93	3.69	2.22	0.36	0.62
448	94.29	3.92	0.52	0.65	0.17
449	84.29	8.81	2.82	0.91	0.56
450[a]	**93.41**	**2.41**	**1.76**	**0.54**	**0.23**
451[a]	**81.05**	**14.61**	**1.48**	**0.53**	**0.21**
452	84.86	11.46	1.14	0.22	0.04
453	88.24	6.39	1.15	1.21	0.39
454	85.58	7.41	2.42	1.93	0.50
455	82.99	9.94	1.54	3.03	1.17
456	85.92	6.05	2.28	2.64	0.91
457	88.12	4.98	2.79	1.16	0.43
458	88.07	4.00	2.44	2.65	0.38
459	89.67	3.10	3.44	0.93	0.75
Average	**85.60**	**6.54**	**3.00**	**1.60**	**0.82**

[a] Permit area selected as white-tailed deer study site

Table 2. Capture data by study site for female white-tailed deer in southwest Minnesota, January 2001.

	Lake Benton			Walnut Grove			Redwood Falls			All Sites		
Age Adult (>1 year) Fawn (~8 months)	Adult	Fawn	Total	Adult	Fawn	Total	Adult	Fawn	Total	Adult	Fawn	Total
Number of deer captured	15	5	20	14	5	19	15	4	19	44	14	58
Mean (SE) handling time (Minutes)	8.9 (0.4)	11.2 (1.3)	9.5 (0.5)	9.2 (0.5)	6.2 (0.9)	8.4 (0.6)	8.1 (0.6)	7.8 (1.1)	8.1 (0.5)	8.8 (0.3)	8.4 (0.8)	8.6 (0.3)
Mean (SE) distance[a] (km)	1.4 (0.2)	0.7 (0.2)	1.2 (0.2)	1.4 (0.2)	1.8 (0.3)	1.5 (0.1)	2.2 (0.2)	1.6 (0.1)	2.1 (0.2)	1.7 (0.1)	1.4 (0.2)	1.6 (0.1)
Mean (SE) rectal temperature (C°)	40.6 (0.2)	40.8 (0.2)	40.6 (0.1)	40.6 (0.2)	41.3 (0.4)	40.8 (0.2)	40.1 (0.2)	41.0 (0.3)	40.3 (0.2)	41.4 (0.1)	41.0 (0.2)	40.6 (0.1)
Mean (SE) neck circumference (cm)	43.1 (0.9)	34.8 (1.5)	41.1 (1.1)	43.2 (0.8)	35.0 (1.6)	41.1 (1.1)	42.8 (0.6)	35.0 (1.1)	41.2 (0.9)	43.1 (0.4)	34.9 (0.8)	41.1 (0.6)
Mean (SE) chest circumference (cm)	109.0 (1.2)	86.8 (2.2)	103.5 (2.4)	106.8 (1.9)	85.4 (1.5)	101.2 (2.7)	108.9 (2.1)	89.3 (2.5)	104.8 (2.5)	108.3 (1.0)	87.0 (1.2)	103.1 (1.5)

[a] Distance (km) between capture site and processing site.

Table 3. Capture data by study site for female white-tailed deer in southwest Minnesota, January 2002.

	Lake Benton	Redwood Falls			All Sites		
Age Adult (>1 year) Fawn (~8months)	Adult[b]	Adult	Fawn	Total	Adult	Fawn	Total
Number of deer captured	8	9	2	11	17	2	19
Mean (SE) handling time (minutes)	6.9 (0.5)	6.1 (0.6)	9.5 (2.5)	6.7 (0.7)	6.4 (0.4)	9.5 (2.5)	6.8 (0.5)
Mean (SE) distance[a] (km)	1.5 (0.2)	2.6 (0.5)	1.5 (0.1)	2.4 (0.4)	2.1 (0.3)	1.5 (0.1)	2.0 (0.3)
Mean (SE) rectal temperature (C°)	40.7 (0.2)	40.6 (0.2)	42.1 (0.0)	40.8 (0.2)	40.6 (0.1)	42.1 (0.0)	40.8 (0.1)
Mean (SE) neck circumference (cm)	45.8 (1.6)	45.2 (1.1)	37.0 (2.0)	43.7 (1.3)	45.5 (0.9)	37.0 (2.0)	44.6 (1.0)
Mean (SE) chest circumference (cm)	102.4 (0.9)	102.3 (1.7)	86.0 (9.0)	99.4 (2.7)	102.4 (1.0)	86.0 (9.0)	100.6 (1.6)

[a] Distance (km) between capture site and processing site.
[b] All deer captured were adults.

Table 4. Cause-specific, seasonal mortality for radiocollared female white-tailed deer in southwest Minnesota, 2001-02.

Cause of mortality	Pre-hunt [b]	Hunting [b]	Post-hunt [b]	Totals
Harvest	0	6	0	6
Vehicle-collision[a]	0	3	1	4
Predation	0	1	0	1
Disease	0	0	1	1
Unknown	0	0	2	2
Totals	0	10	4	14

[a] A deer that died from a train collision was included with vehicle-collision category.
[b] Seasons = Post-hunt (Jan. 1 - April 31), Pre-hunt (May 1 – Aug. 31), Hunting (Sept. 1 - Dec. 31), Hunting-all (Sept. 1 - Dec. 31).

Table 5. Annual survival rates by study site for radiocollared female white-tailed deer in southwest Minnesota, 2001-02.

	Lake Benton	Walnut Grove	Redwood Falls	All sites
Number at-risk	20	19	19	58
Number of deaths	2	5	6	13
Number censored	2	1	2	5
Survival rate	0.8889	0.7270	0.6667	0.7616
Confidence interval (95%)	±0.1452	±0.2065	±0.2178	±0.1138
Variance	0.0055	0.0111	0.0123	0.0034

Table 6. Overall survival rates by study site for radiocollared female white-tailed deer in southwest Minnesota, 2001-02.

	Lake Benton	Walnut Grove	Redwood Falls	All sites
Number at-risk	28	19	30	77
Number of deaths	2	5	7	14
Number censored	3	2	3	8
Survival rate	0.8889	0.7270	0.6364	0.7487
Confidence interval (95%)	±0.1211	±0.2150	±0.1682	±0.0992
Variance	0.0038	0.0120	0.0074	0.0026

Table 7. Survival rates by season for radiocollared female white-tailed deer in southwest Minnesota, 2001-02.

	2001				2002	
Season[a]	Post-hunt[b]	Pre-hunt	Hunting	Hunting-all[c]	Post-hunt	Pre-hunt
Number at-risk	58	53	51	51	60	56
Number of deaths	3	0	6	10	1	0
Number censored	2	2	0	0	3	1
Survival rate	0.9483	1.0000	0.8824	0.8039	0.9833	1.0000
Confidence interval (95%)	±0.0555	±0.0000	±0.0830	±0.0977	±0.0321	±0.0000
Variance	0.0008	0.0000	0.0020	0.0025	0.0003	0.0000

[a] Seasons = Post-hunt (Jan. 1 - April 31), Pre-hunt (May 1 – Aug. 31), Hunting (Sept. 1 - Dec. 31), Hunting-all (Sept. 1 - Dec. 31).
[b] Because deer were captured during the late January, only the end of this month was included in analysis.
[c] Non-hunting (e.g., vehicle, predator) mortalites included during the hunting-all season time period.

Table 8. Annual and overall survival rates by age for radiocollared female white-tailed deer in southwest Minnesota, 2001-02.

	Fawn (~8 months)		Adult (>1 year)	
Time period	Annual	Overall	Annual	Overall
Number at-risk	14	16[a]	44	61[b]
Number of deaths	4	4	9	10
Number censored	2	3	2	5
Survival rate	0.6753	0.6753	0.7871	0.7713
Confidence interval (95%)	±0.2514	±0.2514	±0.1220	±0.1066
Variance	0.0165	0.0165	0.0039	0.0030

[a] Two fawns were added during 2002 capture.
[b] Seventeen adults were added during 2002 capture.

Table 9. Capture data for radiocollared white-tailed deer neonates in southwest Minnesota, spring 2001-02.

	2001			2002			Pooled 2001-02		
Sex	Male	Female	All	Male	Female	All	Male	Female	All
Number of neonates captured	9	12	21	8	10	18	17	22	39
Mean (*n*, SE) handling time (minutes)	2.8 (9, 0.5)	2.4 (12, 0.1)	2.6 (21, 0.2)	4.0 (8, 0.7)	4.7 (10, 07)	4.4 (18, 0.4)	3.4 (17, 0.4)	3.5 (22, 0.4)	3.4 (39, 0.3)
Mean (*n*, SE) age at capture (± 3 days)	5.0 (7, 1.6)	2.9 (11, 0.7)	3.7 (18, 0.8)	5.0 (7, 1.0)	6.7 (9, 1.2)	5.9 (16, .08)	5.0 (14, 0.9)	4.6 (20, 0.8)	4.8 (34, 0.6)

Table 10. Cause-specific, monthly mortality for radiocollared white-tailed deer neonates in southwest Minnesota, summer 2001-02.

Cause of mortality	June	July	August	Totals
Predation	3	0	1	4
Disease	1	0	0	1
Vehicle collision	0	1	0	1
Starvation[a]	2	0	0	2
Totals	5	1	1	8

[a] Unable to determine if neonate mortality was capture-related and was censored from survival analysis.

Table 11. Monthly survival rates for radiocollared white-tailed deer neonates in southwest Minnesota, 2001-02.

	2001			2002			Pooled 2001-02		
Month	June	July	August	June	July	August	June	July	August
Number at-risk	21	19	18	18	13	13	39	32	31
Number of deaths	0	1	0	4	0	1	4	1	1
Number censored	2	0	2	1	0	0	3	0	2
Survival rate	1.0000	0.9470	0.9470	0.7778	0.7778	0.7179	0.8974	0.8694	0.8413
Confidence interval (95%)	±0.0000	±0.0977	±0.1004	±0.1694	±0.1993	±0.2073	±0.0902	±0.1089	±0.1180
Variance	0.0000	0.0025	0.0026	0.0075	0.0103	0.0112	0.0021	0.0031	0.0036

Table 12. Monthly survival rates by sex of radiocollared white-tailed deer neonates in southwest Minnesota, 2001-02.

	Female			Male		
Month	June	July	August	June	July	August
Number at-risk	22	17	16	17	15	15
Number of deaths	3	1	0	1	0	1
Number censored	2	0	0	1	0	2
Survival rate	0.8636	0.8128	0.8128	0.9412	0.9412	0.8784
Confidence interval (95%)	±0.1332	±0.1671	±0.1723	±0.1085	±0.1155	±0.1550
Variance	0.0046	0.0073	0.0077	0.0031	0.0035	0.0063

Table 13. Mean seasonal migration distance by study site for radiocollared white-tailed deer in southwest Minnesota, 2001-02.

	Lake Benton	Walnut Grove	Redwood Falls	All Deer
2001 Spring Migration[a] (km), (*n*, SE)	8.5 (16, 1.2)	7.8 (14, 2.2)	11.6 (12, 2.2)	8.8 (40, 1.1)
2001 Winter Migration[a] (km), (*n*, SE)	9.3 (10, 1.0)	13.6 (8, 4.0)	11.2 (5, 4.0)	11.2 (23, 1.7)
2002 Spring Migration[a] (km), (*n*, SE)	9.4 (18, 1.2)	13.8 (5, 4.8)	11.2 (8, 2.5)	10.8 (32, 1.2)
Pooled Migration[a] (km), (*n*, SE)	9.1 (44, 0.7)	10.7 (27, 1.9)	11.4 (25, 1.6)	10.1 (95, 0.7)

[a] Distance of deer movement between winter and summer home ranges.

Table 14. Seasonal home range size by study site for radiocollared female white-tailed deer in southwest Minnesota, 2001-02.

	Lake Benton	Walnut Grove	Redwood Falls	All Sites
Winter 50% (km^2), (*n*, SE)	1.02 (11, 0.33)	0.96 (12, 0.20)	0.54 (14, 0.10)	0.82 (37, 0.13)
Winter 95% (km^2), (*n*, SE)	6.91 (11, 2.13)	5.66 (12, 1.03)	3.42 (14, 0.70)	5.18 (37, 0.78)
Summer 50% (km^2), (*n*, SE)	0.40 (36, 0.06)	0.33 (26, 0.05)	0.28 (31, 0.04)	0.34 (93, 0.03)
Summer 95% (km^2), (*n*, SE)	2.65 (36, 0.36)	2.25 (26, 0.29)	1.84 (31, 0.21)	2.27 (93, 0.18)

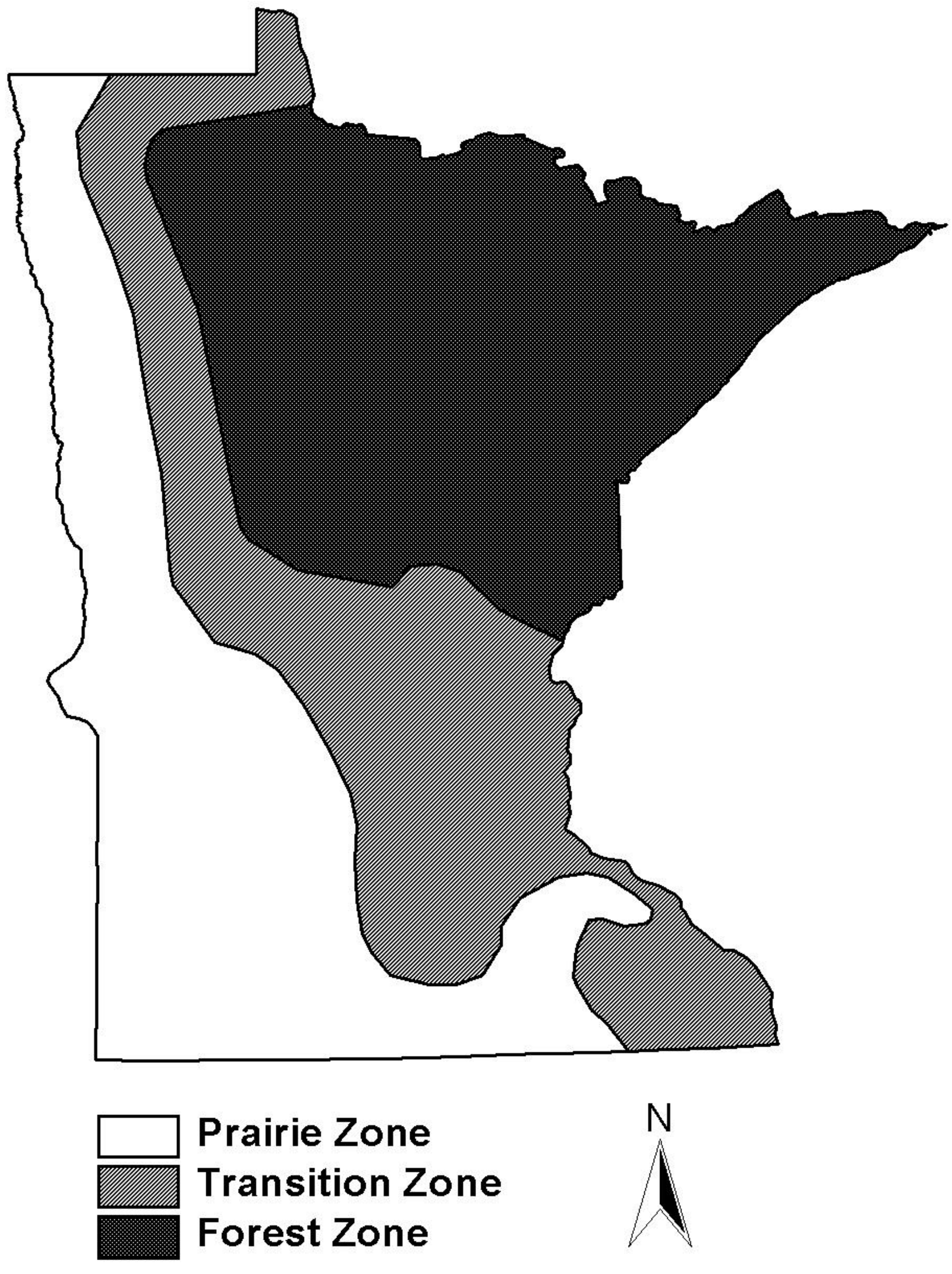

Figure 1. Pre-settlement vegetation zones of Minnesota (Rosendahl and Butters 1928).

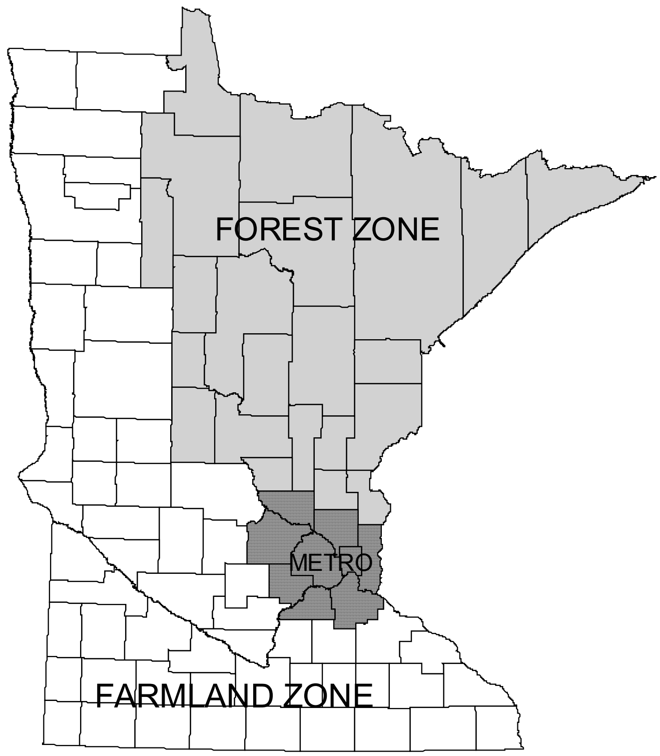

Figure 2. Farmland, Forest, and Metro Zones of Minnesota (DePerno et al. 1999).

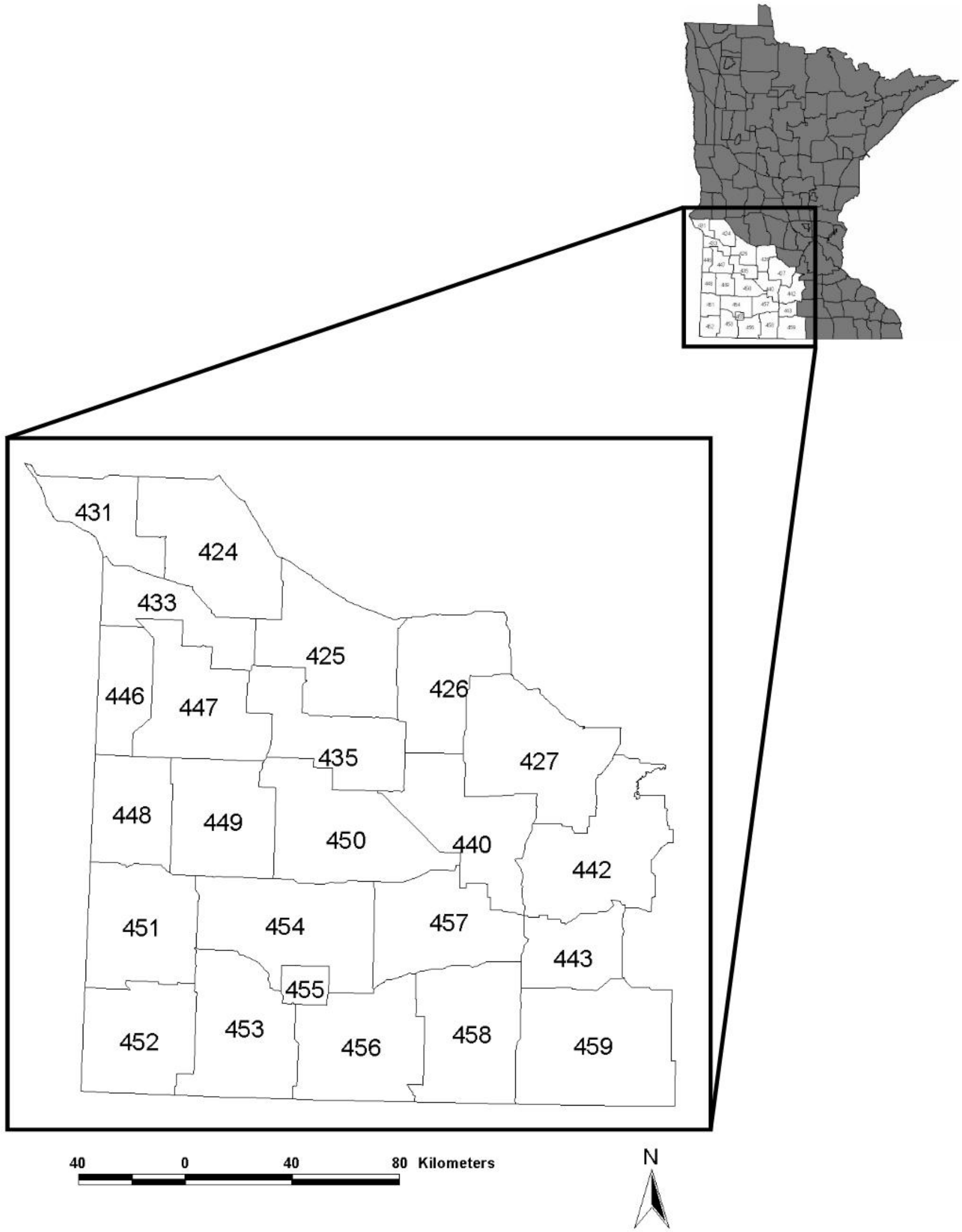

Figure 3. Southwest Minnesota white-tailed deer permit areas (PAs), 2000.

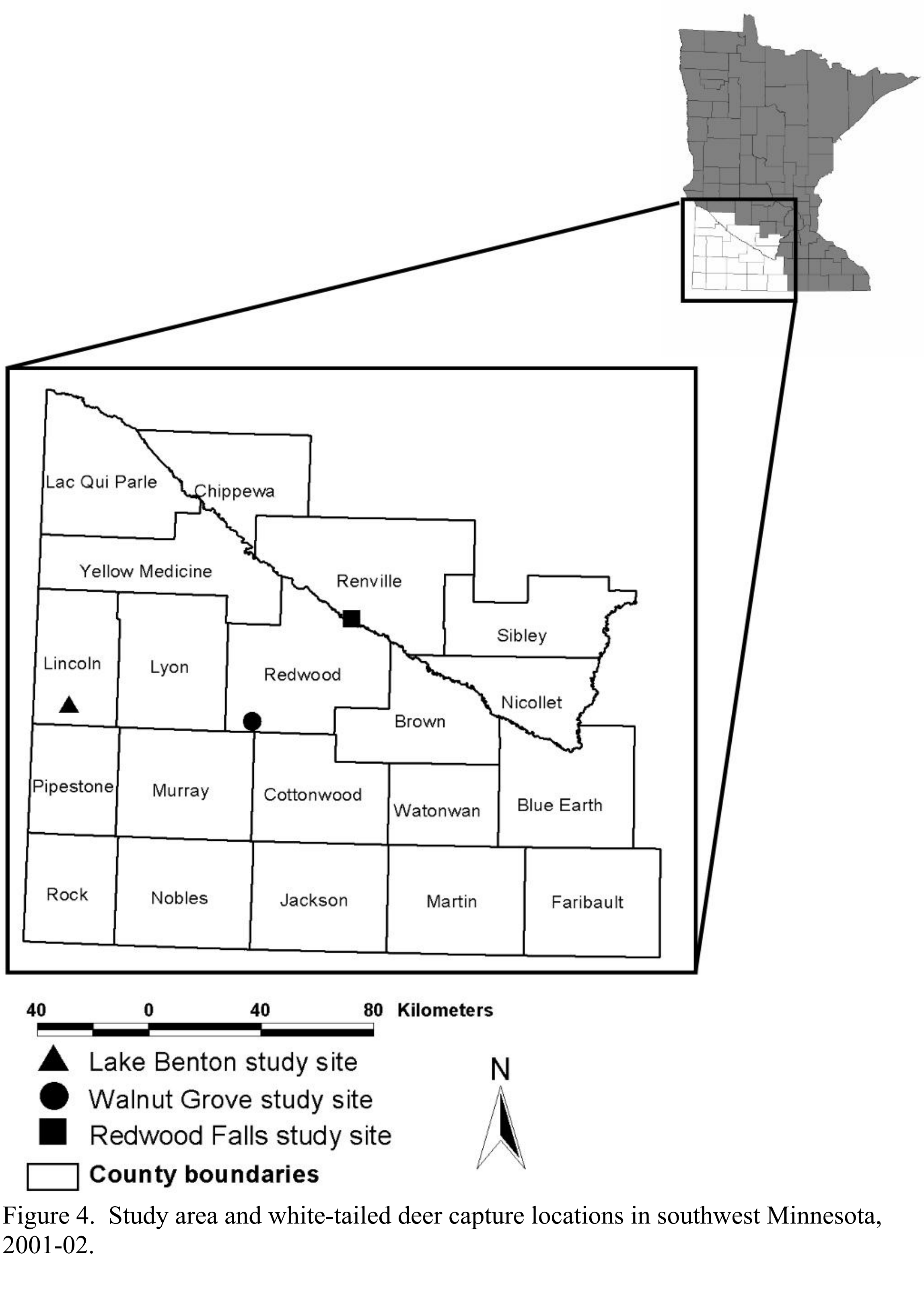

Figure 4. Study area and white-tailed deer capture locations in southwest Minnesota, 2001-02.

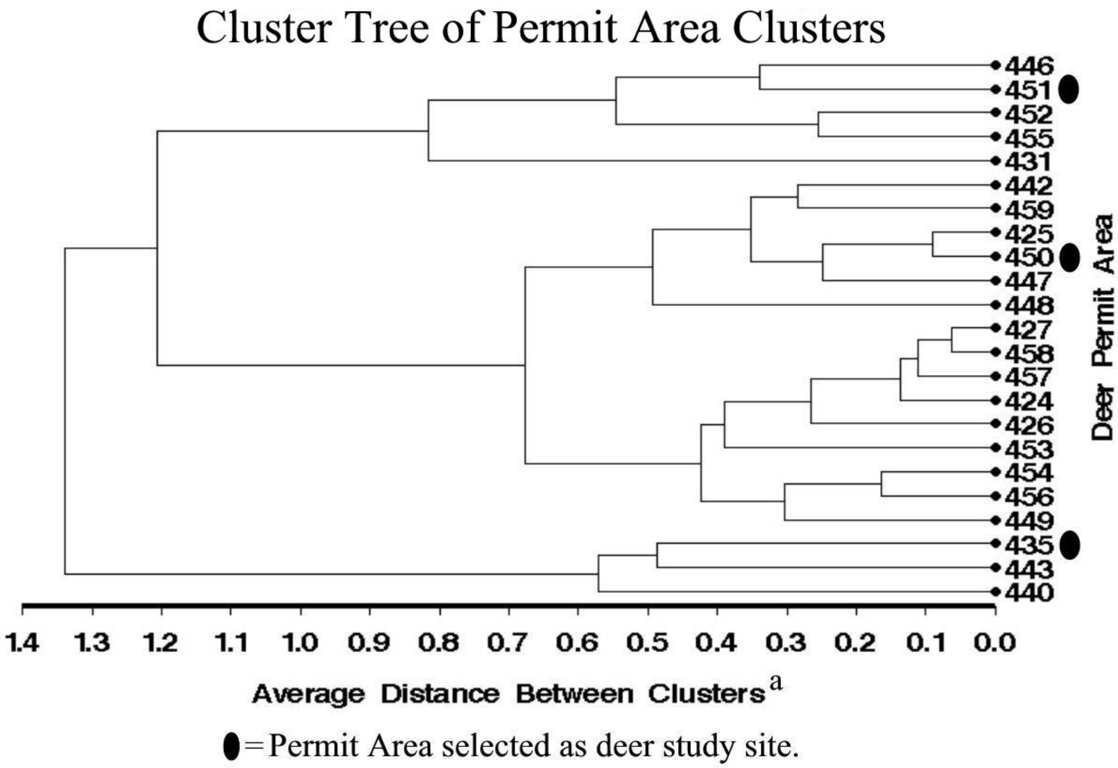

Figure 5. Hierarchical cluster tree diagram for deer permit areas in southwest Minnesota. The average distance between clusters (x axis) is defined as "the average of all the dissimilarities between all possible pairs of points such that one of each pair is in each cluster" (Johnson 1998).

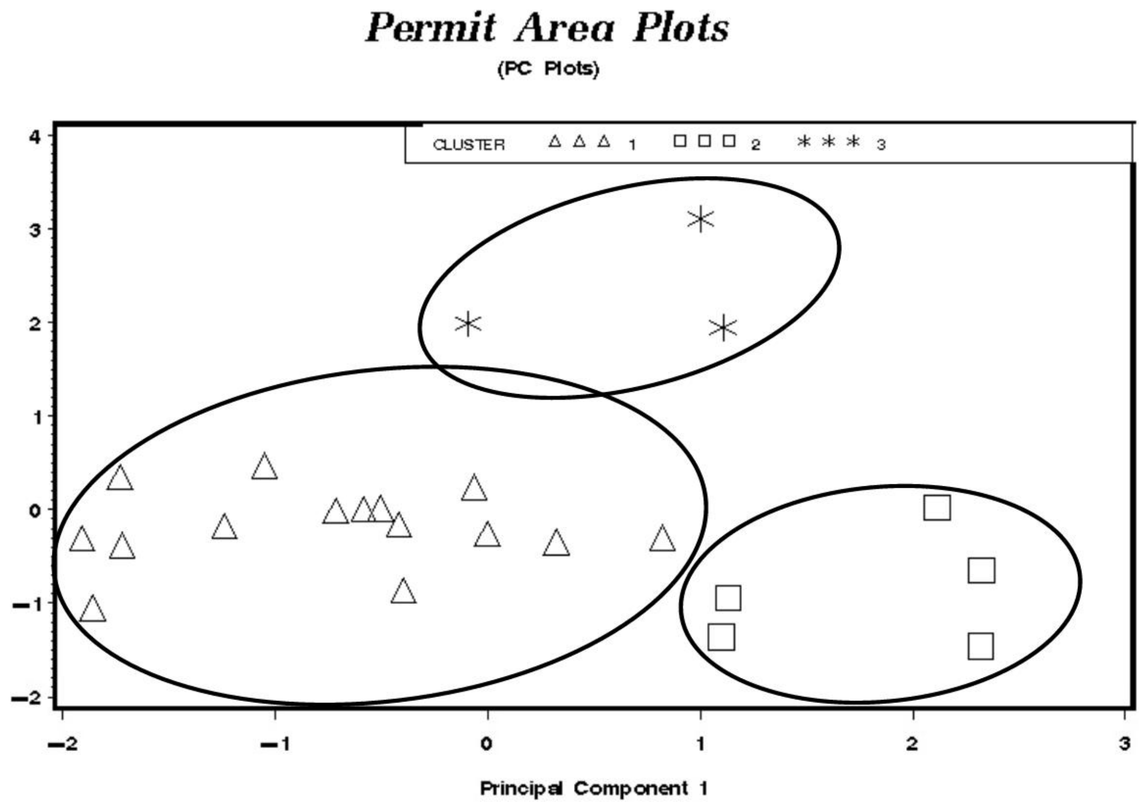

Figure 6. Principal components analysis clusters of scores for deer permit areas in southwest Minnesota, 2000.

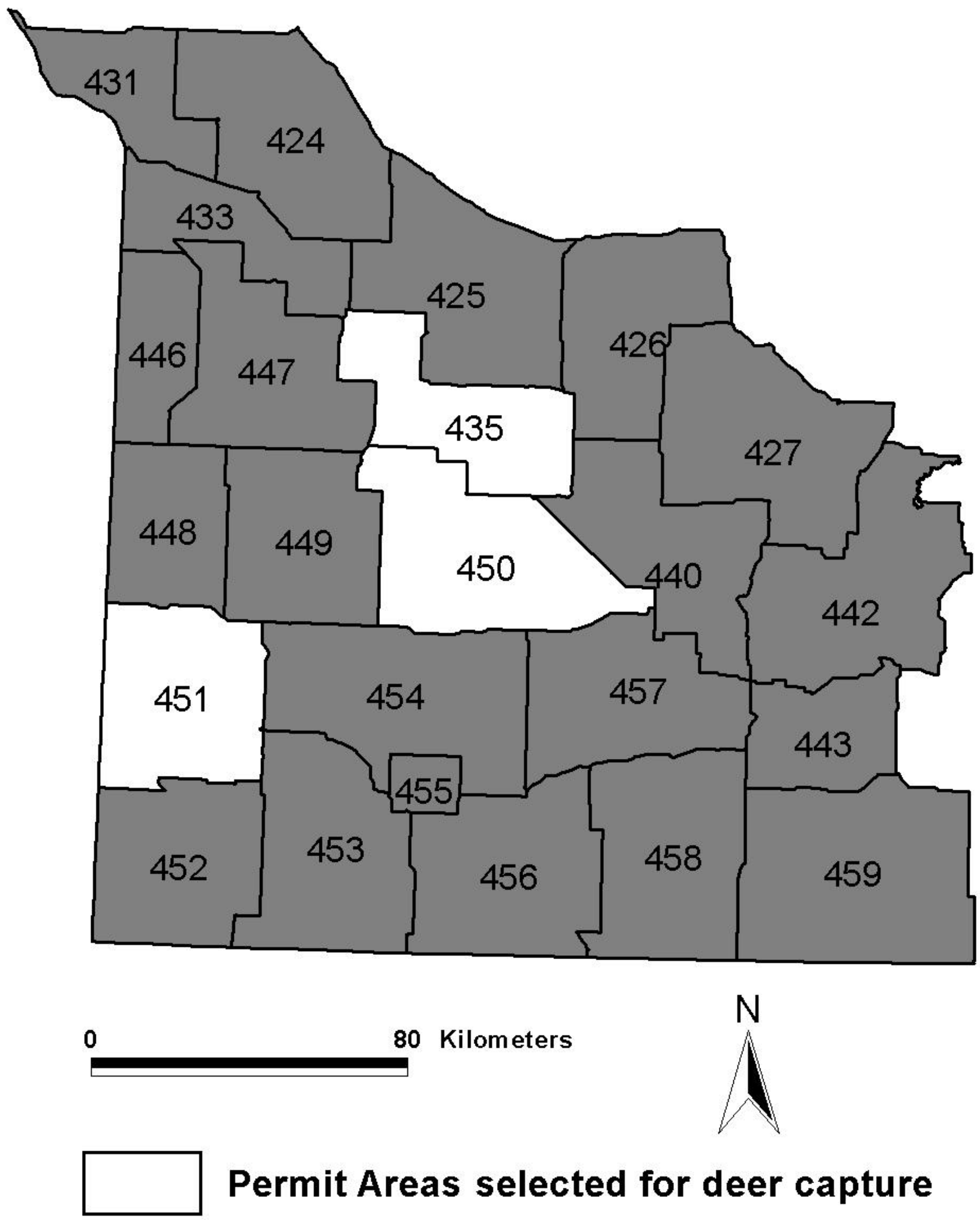

Figure 7. Permit areas selected for white-tailed deer capture sites in southwest Minnesota, 2001-02.

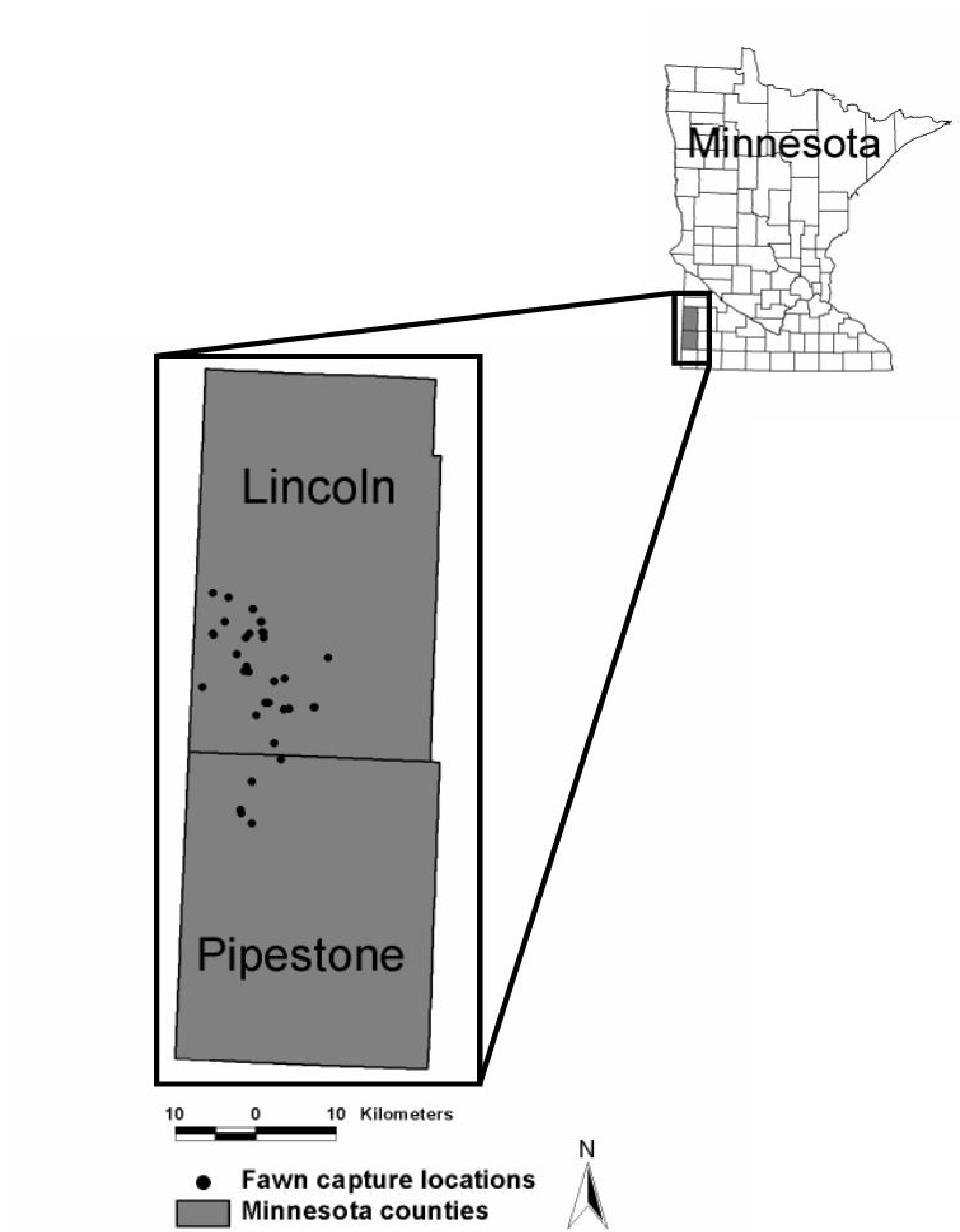

Figure 8. White-tailed deer neonate study area and capture locations in southwest Minnesota, 2001-02.

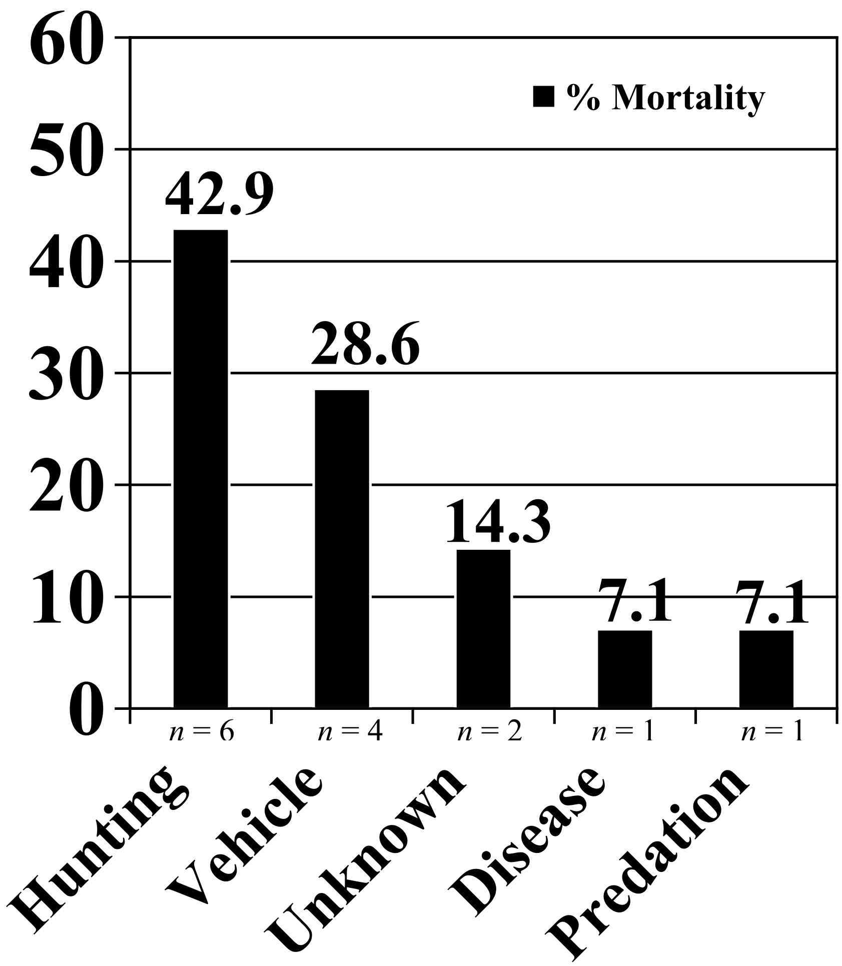

Figure 9. Cause-specific mortality of radiocollared female white-tailed deer in southwest Minnesota, 2001-02 (Deer that died from train collision was included in vehicle mortalities).

Carcass cached under fallen tree, covered with ground deris (e.g., leaves, grass, twigs)

Abrasions and claw marks on rump penetrating into the flesh

Rightside front and rear legs fed on to the bone

Throat puncture marks with bruising and hemorrhaging under the skin

Figure 10. Suspected felid (i.e., bobcat, cougar) killed 2.5-year old female white-tailed deer in southwest Minnesota, 16 October 2001.

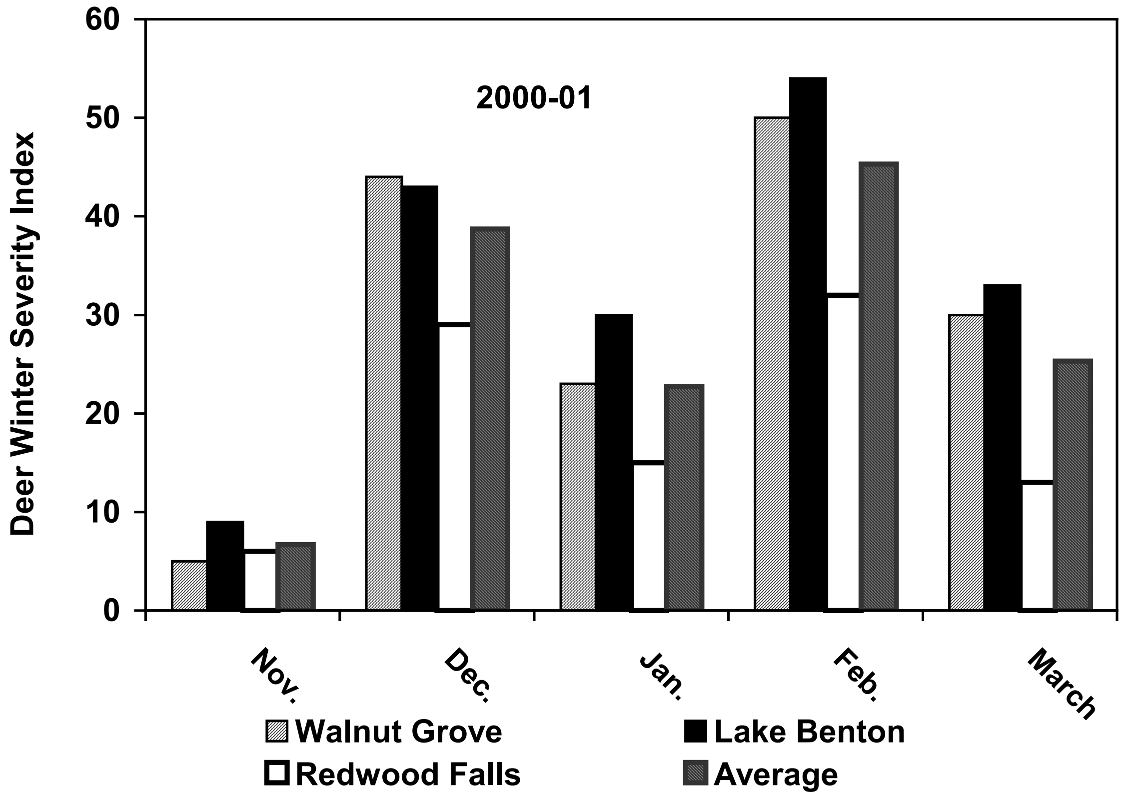

Figure 11. Monthly deer winter severity index (DWSI) for individual study sites in southwest Minnesota, 2000-01. (One point accumulated for each day with an ambient temperature ≤-7 C°, and an additional point accumulated for each day with snow depths ≥35.0 cm; National Climatic Data Center 2002, Climatology Working Group 2003).

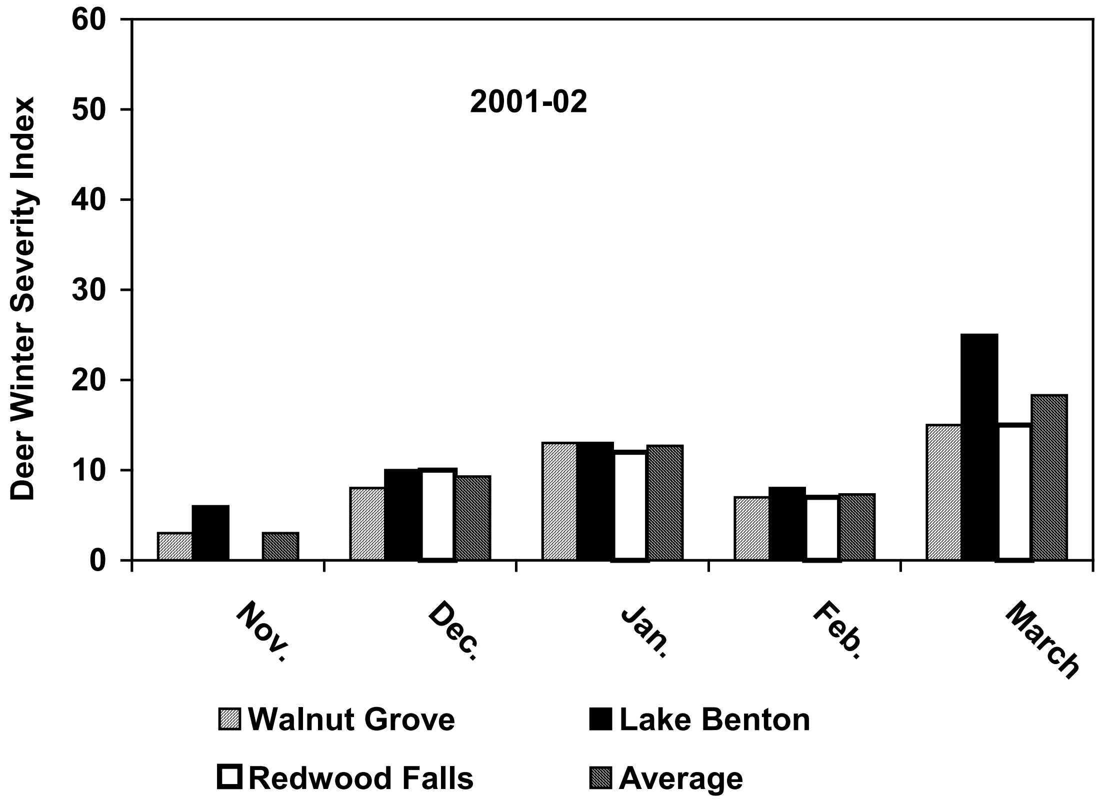

Figure 12. Monthly deer winter severity index (DWSI) for individual study sites in southwest Minnesota, 2001-02. (One point accumulated for each day with an ambient temperature ≤-7 C°, and an additional point accumulated for each day with snow depths ≥35.0 cm; National Climatic Data Center 2002, Climatology Working Group 2003).

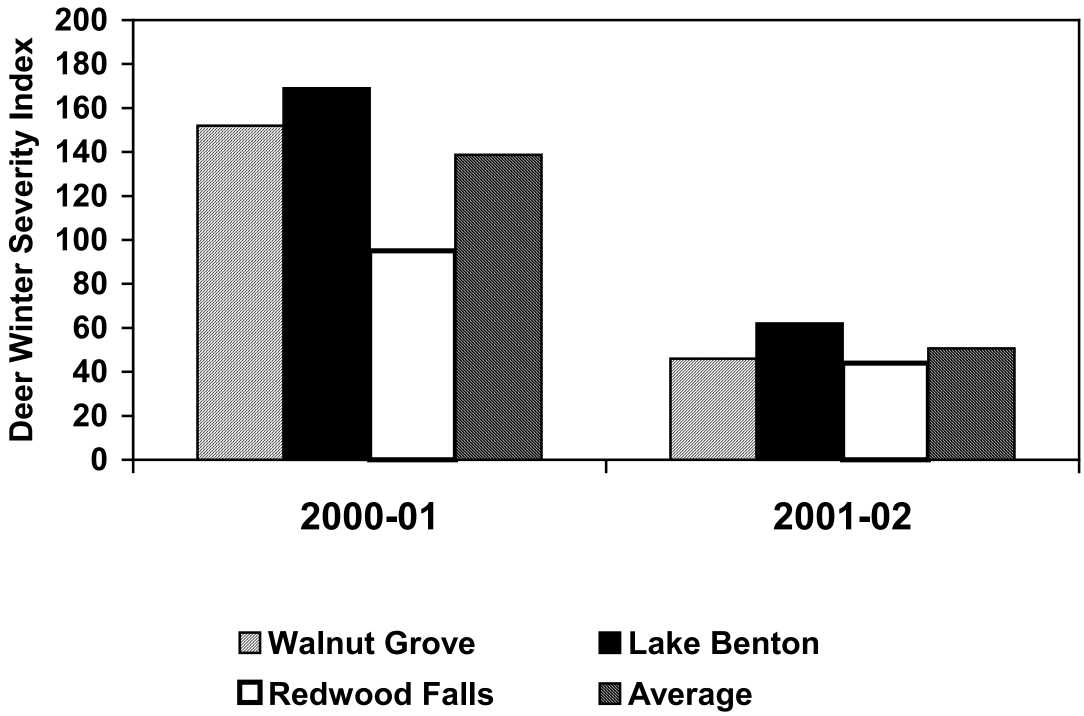

Figure 13. Annual deer winter severity index (DWSI) for individual study sites in southwest Minnesota, 2000-02. (One point accumulated for each day between November and March with an ambient temperature ≤-7 C°, and an additional point accumulated for each day with snow depths ≥35.0 cm; National Climatic Data Center 2002, Climatology Working Group 2003)).

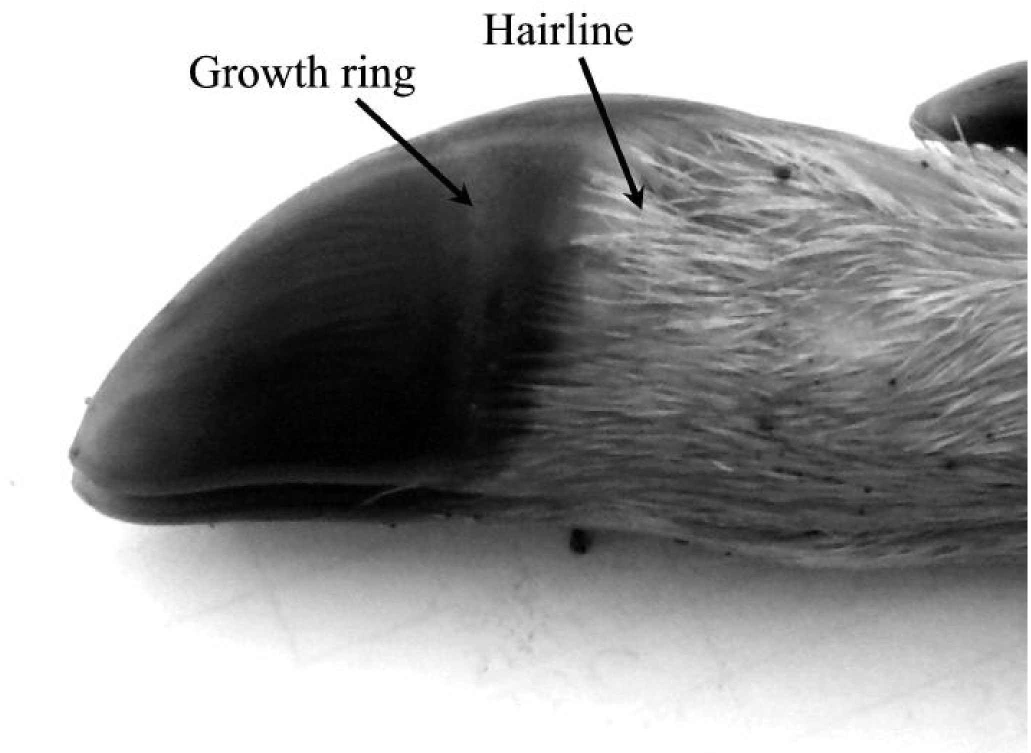

Figure 14. To determine the age of white-tailed deer neonates, the distance from growth ring to hairline was measured (mm) on front hoof (Haugen and Speak 1958).

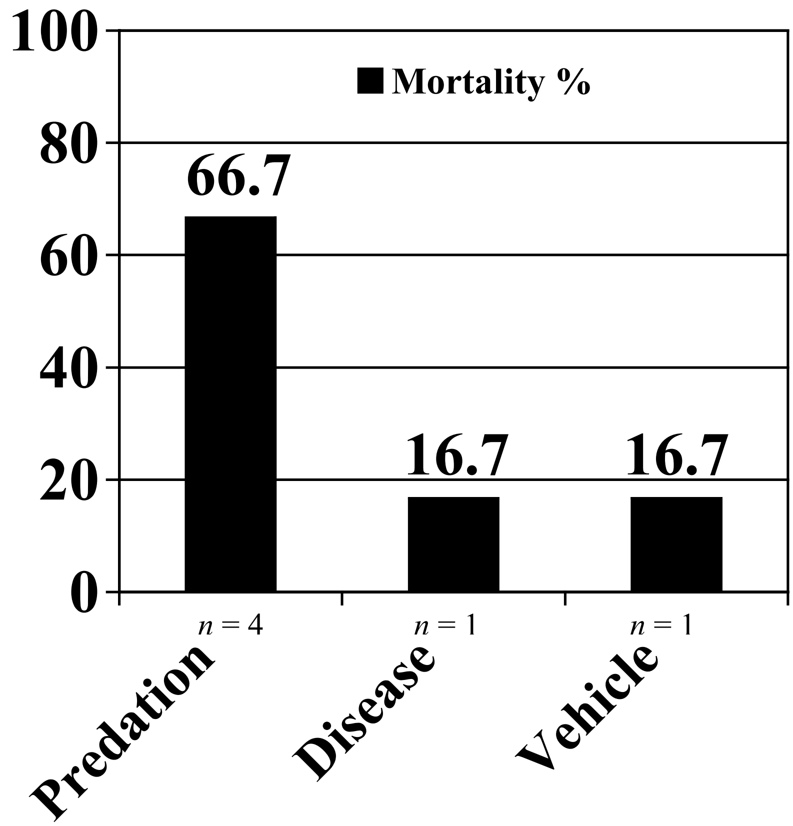

Figure 15. Cause-specific mortality for radiocollared white-tailed deer neonates in southwest Minnesota, summer 2001-02.

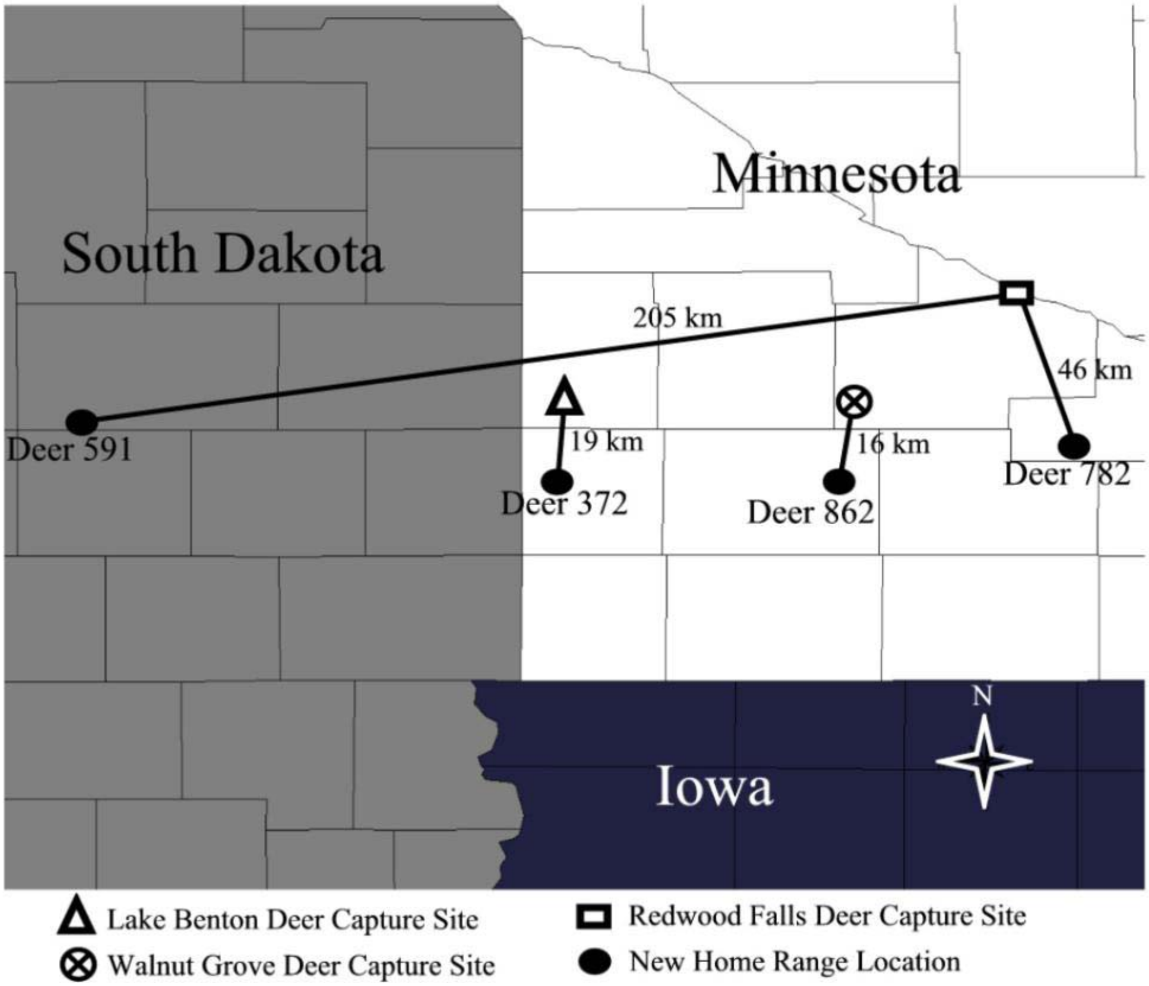

Figure 16. Dispersal distance and direction for radiocollared female white-tailed deer in southwest Minnesota, 2001.

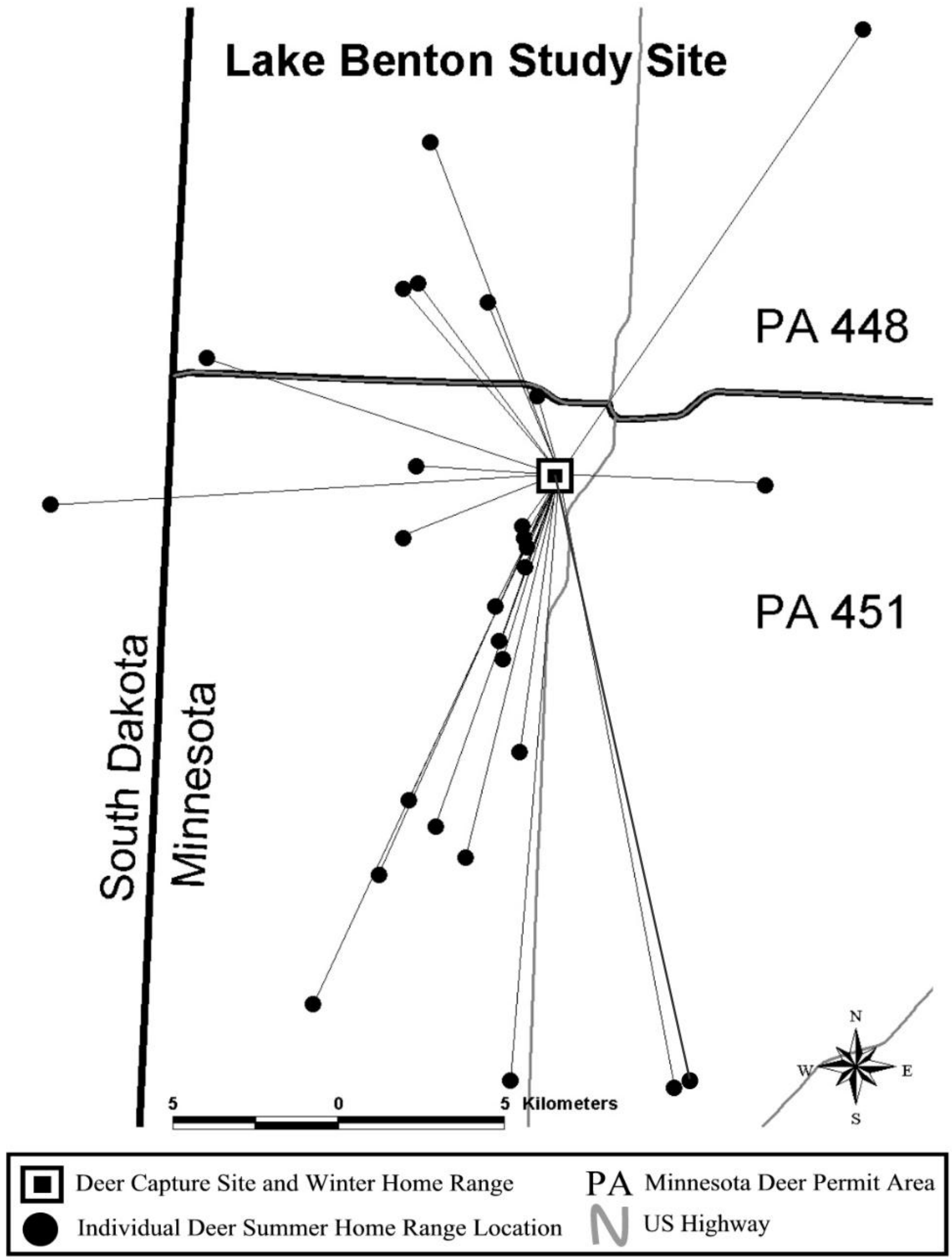

Figure 17. Migrations for radiocollared female white-tailed deer at Lake Benton study site in southwest Minnesota, 2001-02 (Refer to Figure 4 for location of study sites in southwest Minnesota).

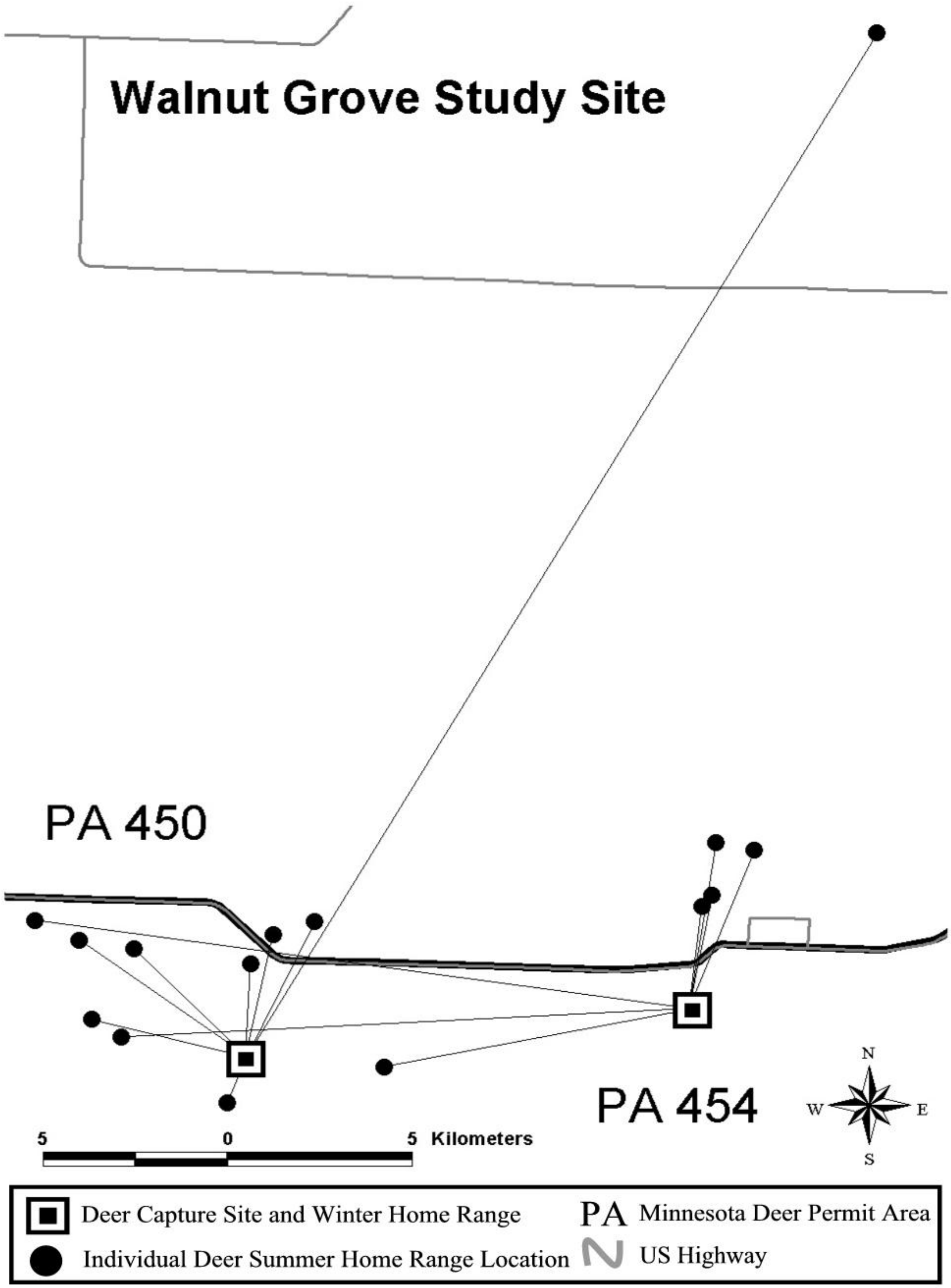

Figure 18. Migrations for radiocollared female white-tailed deer at Walnut Grove study site in southwest Minnesota, 2001-02 (Refer to Figure 4 for location of study sites in southwest Minnesota).

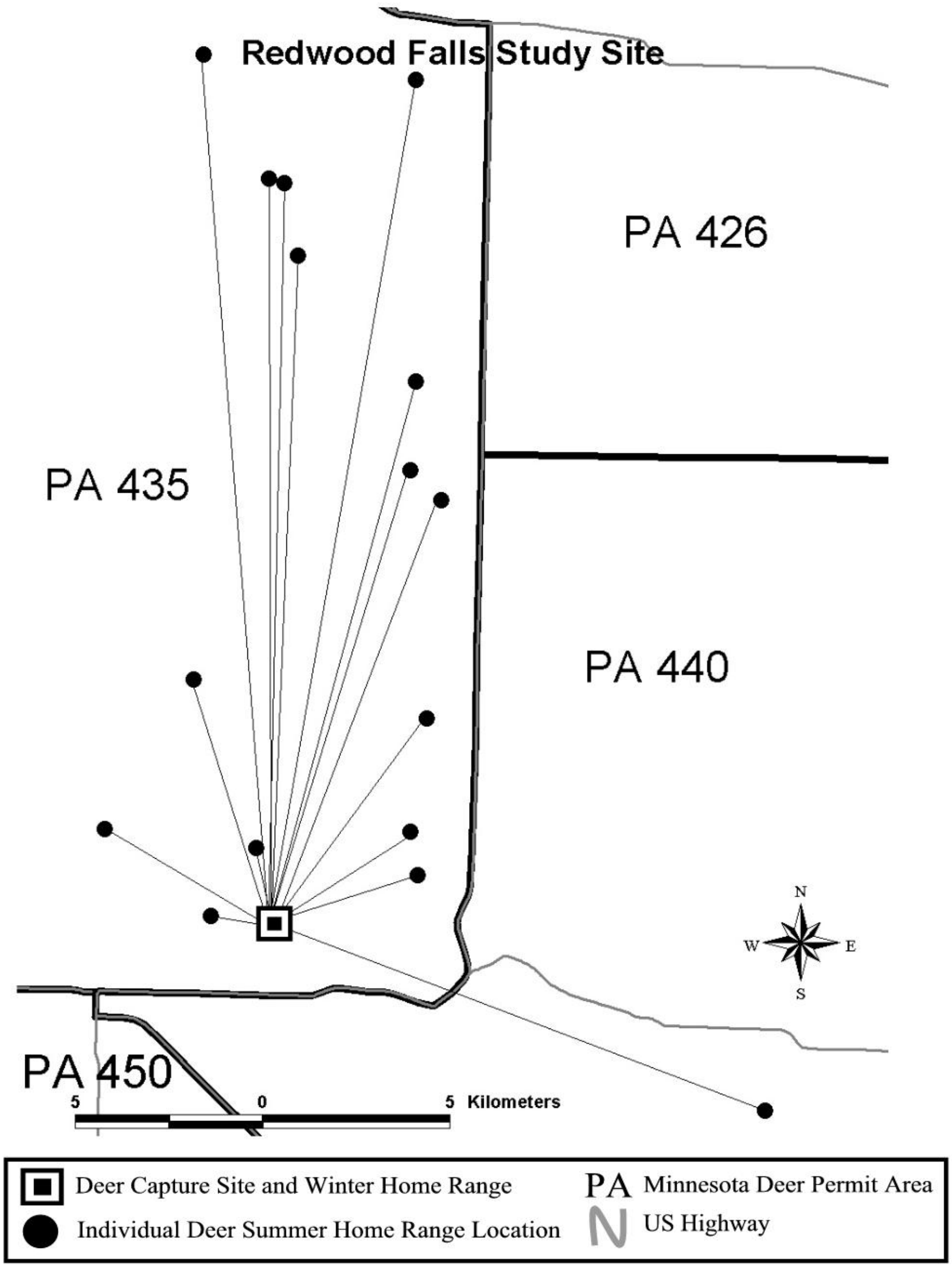

Figure 19. Migrations for radiocollared female white-tailed deer at Redwood Falls study site in southwest Minnesota, 2001-02 (Refer to Figure 4 for location of study sites in southwest Minnesota).

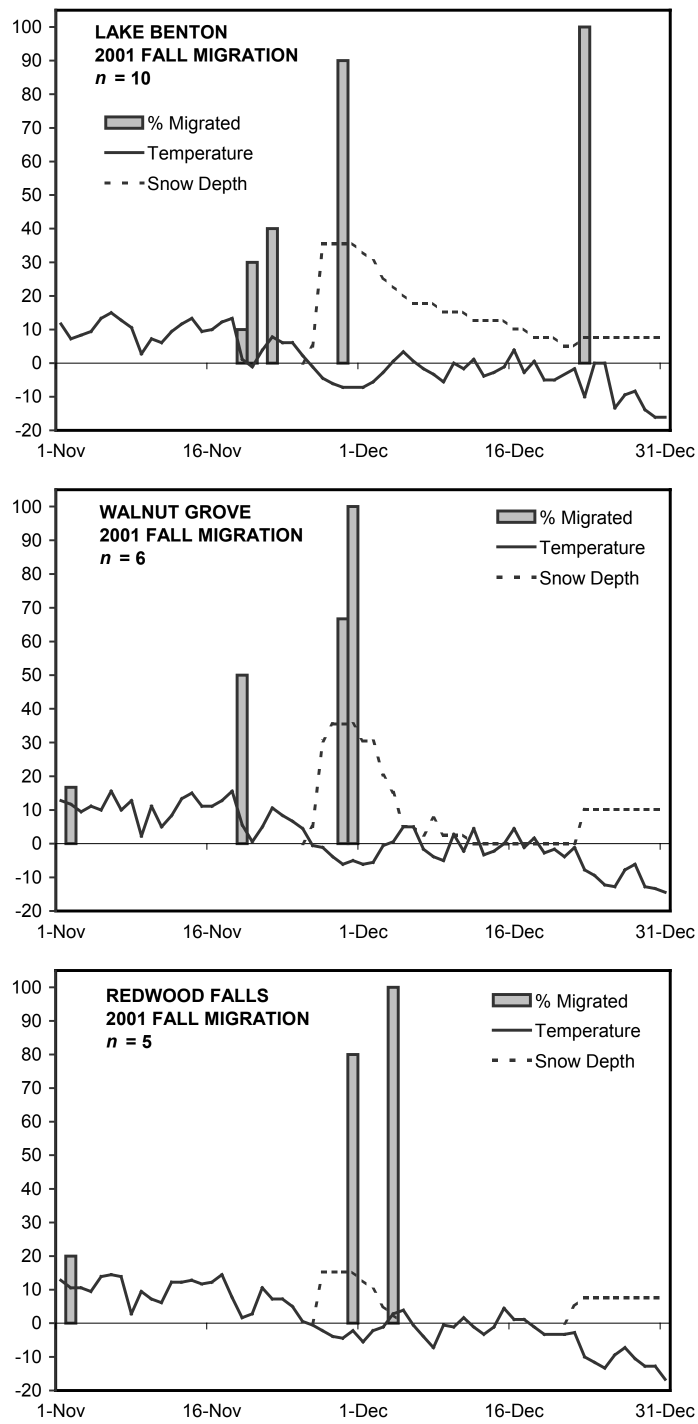

Figure 20. Fall migration events by study site for radiocollared female white-tailed deer in southwest Minnesota, 2001. The Y-axis is shared by all three variables (i.e., temperature [C°], snow depth [cm], migrating [%]). A migration event represents the cumulative percentage of migating individuals at each study site with known departure dates from summer range.

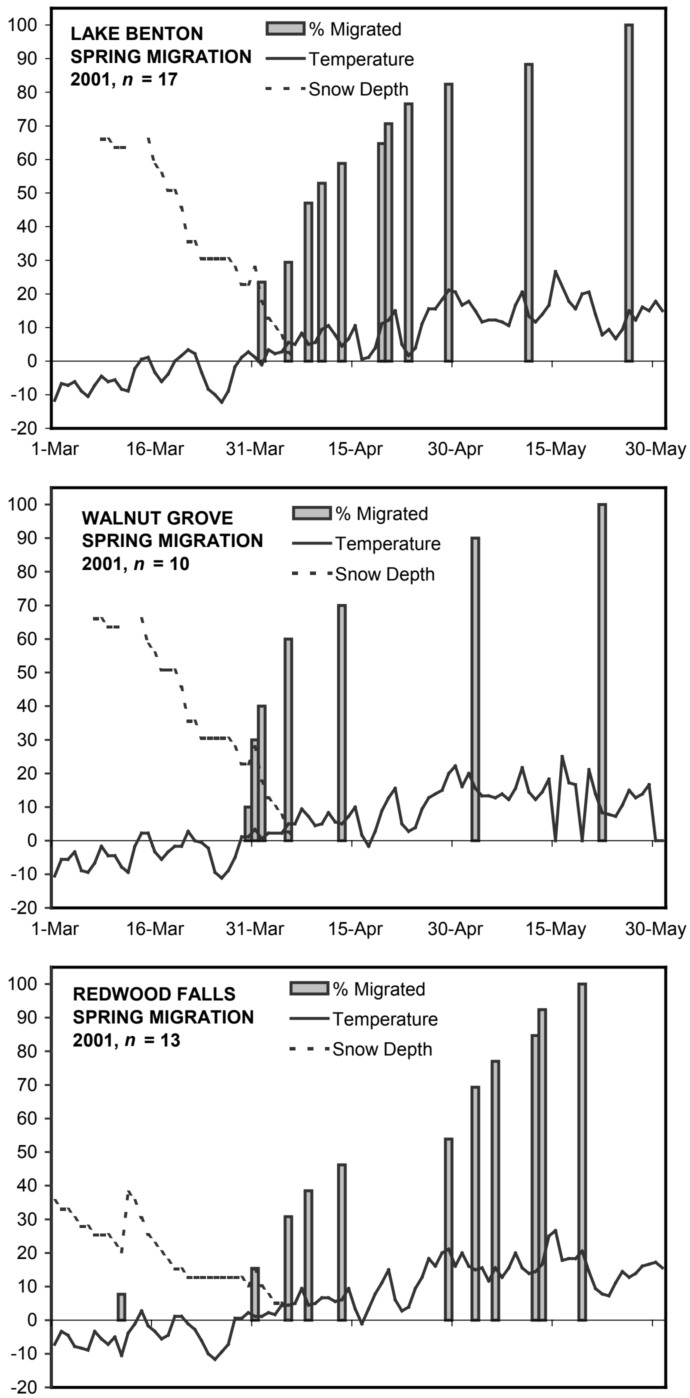

Figure 21. Spring migration events by study site for radiocollared female white-tailed deer in southwest Minnesota, 2001. The Y-axis is shared by all three variables (i.e., temperature [C°], snow depth [cm], migrating [%]). A migration event represents the cumulative percentage of migrating individuals at each study site with known departure dates from winter range.

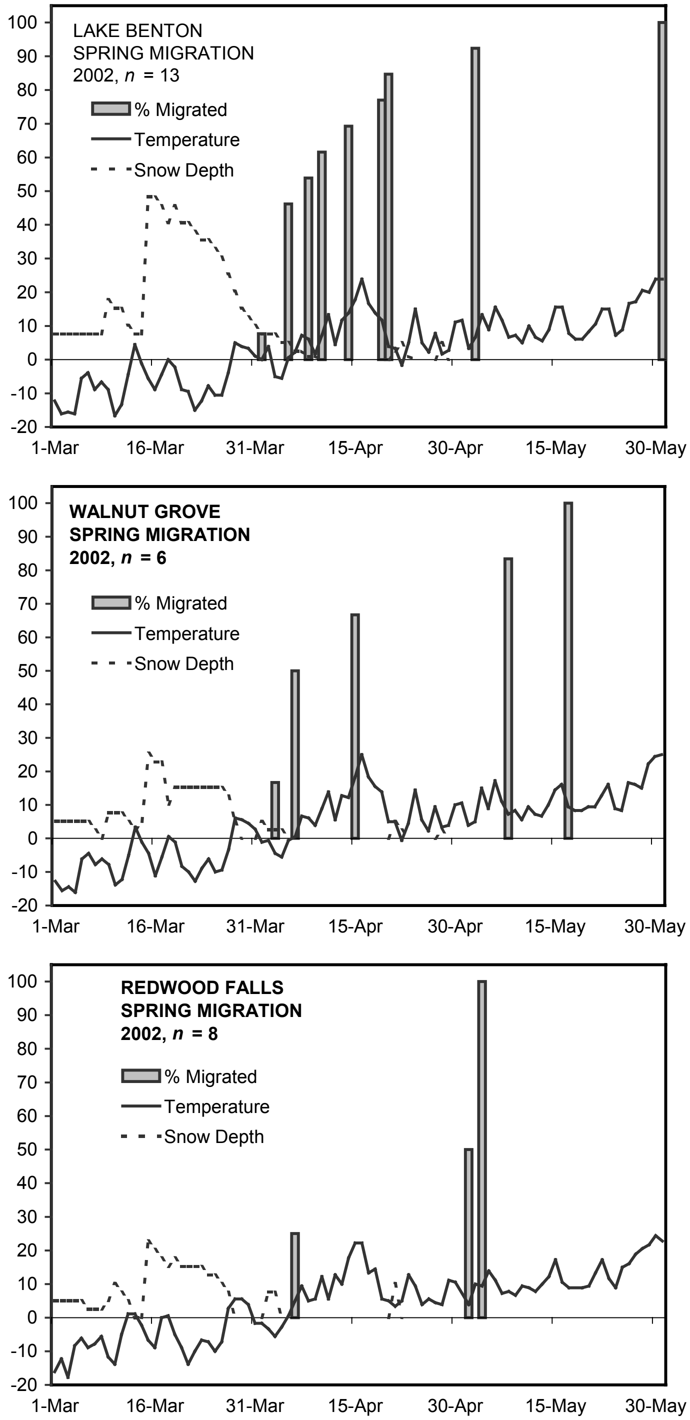

Figure 22. Spring migration events by study site for radiocollared female white-tailed deer in southwest Minnesota, 2002. The Y-axis is shared by all three variables (i.e., temperature [C°], snow depth [cm], migrating [%]). A migration event represents the cumulative percentage of migrating individuals at each study site with known departure dates from winter range.

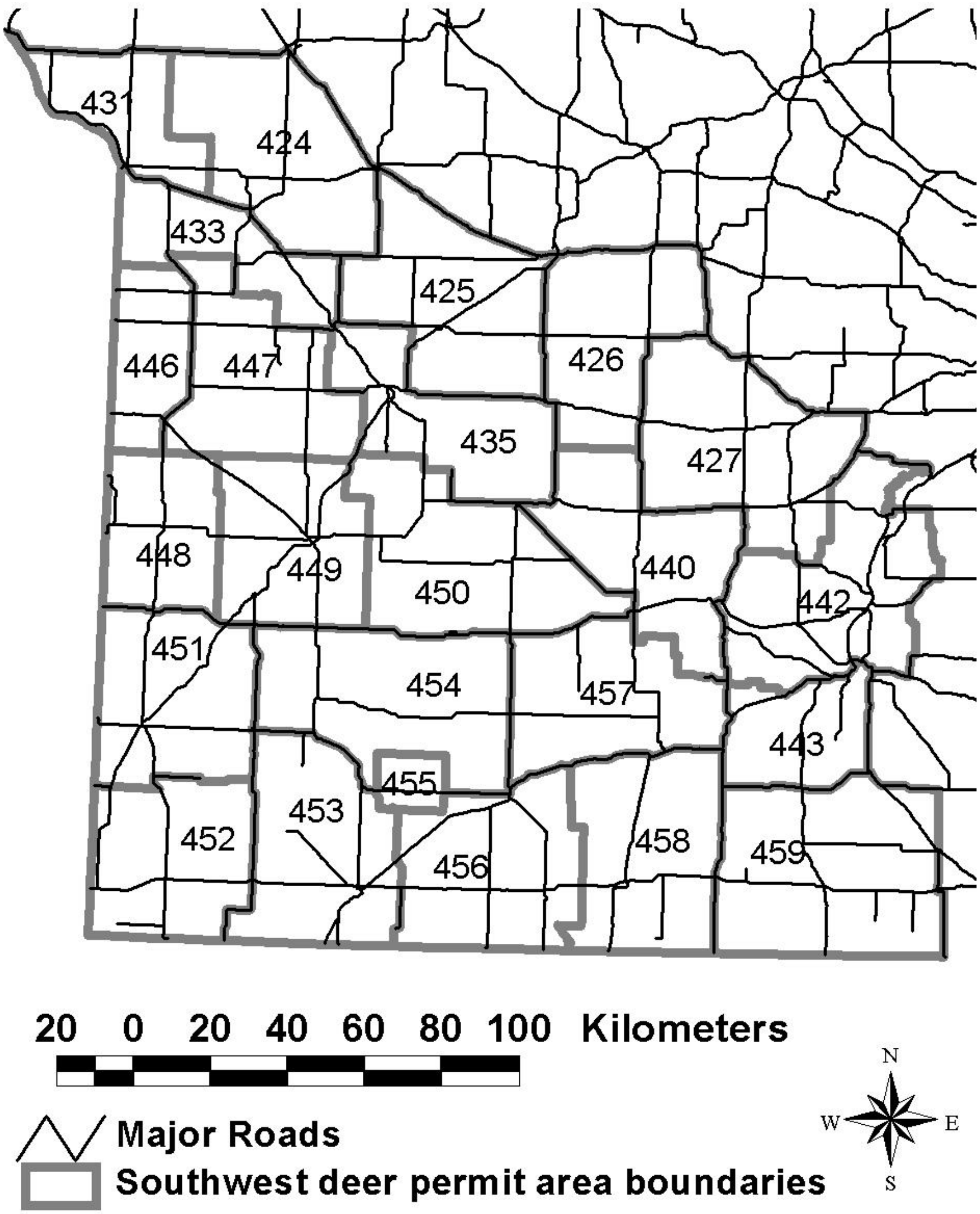

Figure 23. Southwest Minnesota deer permit areas and major roads, 2000.

Appendix A. Capture data for radiocollared female white-tailed deer in southwest Minnesota, January 2001.

Capture Date	Study Site	Age at capture (fawn, adult)	Collar Frequency	Processing Time	Rectal Temp. C°	Neck Girth (cm)	Chest Girth (cm)	Left ear tag #	Right ear tag #	Transport distance (km)
1/24/01	Redwood Falls	A	232	6.00	39.6	41	121	1273	1274	3.57
1/24/01	Redwood Falls	A	410	6.00	40.4	45	113	1275	1225	3.36
1/24/01	Redwood Falls	A	352	6.00	39.5	42	108	1223	1224	1.48
1/24/01	Redwood Falls	A	470	7.00	39.5	42	110	1220	1221	1.85
1/24/01	Redwood Falls	A	171	6.00	40.3	46	109	1219	1222	2.17
1/24/01	Redwood Falls	F	811	6.00	41.4	33	86	1217	1216	1.48
1/24/01	Redwood Falls	F	782	7.00	41.1	34	93	1215	1214	2.06
1/24/01	Redwood Falls	A	289	9.00	39.2	45	113	1165	1166	3.27
1/24/01	Redwood Falls	A	111	7.00	40.2	43	122	1167	1168	2.54
1/24/01	Redwood Falls	F	901	7.00	41.5	35	95	1169	1170	1.50
1/24/01	Redwood Falls	A	689	9.00	41.1	44	111	1171	1172	2.66
1/24/01	Redwood Falls	A	631	11.00	39.0	41	94	1173	1174	0.87
1/24/01	Redwood Falls	A	722	6.00	39.5	39	101	1213	1212	1.98
1/23/01	Redwood Falls	F	841	11.00	40.0	38	83	1265	1264	1.50
1/23/01	Redwood Falls	A	662	11.00	40.3	38	116	1269	1266	0.00
1/23/01	Redwood Falls	A	531	7.00	40.6	46	106	1163	1164	2.54
1/23/01	Redwood Falls	A	054	14.00	41.1	45	111	1162	1161	1.77
1/23/01	Redwood Falls	A	591	10.00	40.4	42	98	no data	1270	2.24
1/23/01	Redwood Falls	A	750	7.00	41.1	43	101	1271	1272	2.64
1/23/01	Walnut Grove	A	741	10.00	40.8	41	105	1158	1157	1.34
1/23/01	Walnut Grove	A	622	7.00	40.3	47	114	1159	1160	1.26
1/23/01	Walnut Grove	A	331	7.00	41.4	47	107	1155	1156	1.42
1/23/01	Walnut Grove	A	210	10.00	40.1	43	119	1259	1258	1.48
1/23/01	Walnut Grove	F	803	7.00	40.8	29	81	1261	1260	1.43
1/23/01	Walnut Grove	F	032	8.00	41.7	36	83	1263	1262	1.66
1/23/01	Walnut Grove	A	653	12.00	38.9	41	102	1149	1150	1.77
1/23/01	Walnut Grove	A	091	10.00	41.8	46	106	1153	1154	1.37
1/23/01	Walnut Grove	F	890	4.00	41.6	36	89	1247	1248	0.95

1/23/01	Walnut Grove	A	510	6.00	40.3	44	119	1250	1249	0.43
1/23/01	Walnut Grove	A	148	11.00	40.5	40	114	1142	1141	1.40
1/23/01	Walnut Grove	A	571	9.00	39.9	46	106	1246	1251	0.93
1/23/01	Walnut Grove	F	862	4.00	42.2	36	88	1253	1252	2.33
1/23/01	Walnut Grove	A	390	10.00	40.7	45	103	1255	1254	2.41
1/23/01	Walnut Grove	A	710	12.00	41.3	39	94	1147	1148	0.66
1/23/01	Walnut Grove	A	449	9.00	40.2	45	104	1245	1244	2.06
1/23/01	Walnut Grove	A	271	10.00	40.5	41	102	1143	1144	0.64
1/23/01	Walnut Grove	A	680	6.00	42.2	40	100	1145	1146	1.77
1/23/01	Walnut Grove	F	832	8.00	40.1	38	86	1256	1257	2.56
1/22/01	Lake Benton	A	731	11.00	40.0	48	105	1025	1026	1.43
1/22/01	Lake Benton	A	193	10.00	41.3	46	104	1121	1122	0.72
1/22/01	Lake Benton	F	761	11.00	40.4	40	95	1123	1124	1.09
1/22/01	Lake Benton	A	131	8.00	39.9	41	111	1127	1128	2.95
1/22/01	Lake Benton	A	372	9.00	40.6	42	113	1129	1130	1.05
1/22/01	Lake Benton	A	672	12.00	41.1	49	108	1131	1132	1.24
1/22/01	Lake Benton	A	072	9.00	41.8	38	101	1235	1234	2.11
1/22/01	Lake Benton	A	011	6.00	39.9	41	107	1136	1135	1.50
1/22/01	Lake Benton	F	853	13.00	40.4	35	87	1238	1239	0.23
1/22/01	Lake Benton	A	551	10.00	40.9	40	112	1241	1240	1.00
1/22/01	Lake Benton	F	881	15.00	41.0	31	83	1243	1242	0.80
1/22/01	Lake Benton	F	790	9.00	41.4	35	86	1133	1134	1.24
1/22/01	Lake Benton	F	821	8.00	40.6	33	83	1137	1138	0.23
1/22/01	Lake Benton	A	309	11.00	39.9	40	114	1139	1140	1.19
1/22/01	Lake Benton	A	250	9.00	40.5	39	112	1233	1232	0.35
1/22/01	Lake Benton	A	491	9.00	40.5	42	108	1025	1026	1.09
1/22/01	Lake Benton	A	611	7.00	41.0	45	101	1237	1236	1.42
1/22/01	Lake Benton	A	643	7.00	40.0	46	115	1226	1227	1.46
1/22/01	Lake Benton	A	430	8.00	40.9	44	109	1229	1228	2.08
1/22/01	Lake Benton	A	702	8.00	40.3	46	115	1231	1230	0.89

Appendix B. Capture data for radiocollared female white-tailed deer in southwest Minnesota, January 2002.

Capture Date	Study Site	Age at capture (fawn, adult)	Collar Frequency	Processing Time	Rectal Temp. C°	Neck Girth (cm)	Chest Girth (cm)	Left ear tag #	Right ear tag #	Transport distance (km)
1/26/02	Lake Benton	A	032B	7.00	40.5	52	107	1301	1302	1.28
1/26/02	Lake Benton	A	352B	9.00	40.6	48	100	1337	1336	2.04
1/26/02	Lake Benton	A	551B	9.00	39.9	44	104	1335	1334	1.18
1/26/02	Lake Benton	A	771B	5.00	40.8	45	101	1303	1304	1.67
1/26/02	Lake Benton	A	803B	6.00	40.2	41	99	1333	1332	2.11
1/26/02	Lake Benton	A	832B	5.00	41.5	42	101	1331	1330	0.85
1/26/02	Lake Benton	A	868B	7.00	40.8	52	103	1327	1326	1.70
1/26/02	Lake Benton	A	901B	7.00	41.1	42	104	1329	1328	1.06
1/26/02	Redwood Falls	A	149B	4.00	39.8	50	101	1306	1305	2.46
1/26/02	Redwood Falls	A	171B	5.00	40.1	41	93	1310	1309	2.41
1/26/02	Redwood Falls	F	193B	12.00	42.1	35	77	1346	1347	1.60
1/26/02	Redwood Falls	A	391B	10.00	40.2	47	109	1308	1307	2.07
1/26/02	Redwood Falls	A	512B	5.00	40.7	47	103	1312	1311	0.56
1/26/02	Redwood Falls	A	680B	6.00	41.4	47	102	1314	1313	4.21
1/26/02	Redwood Falls	F	702B	7.00	42.1	39	95	1344	1345	1.46
1/26/02	Redwood Falls	A	770B	6.00	40.7	47	110	1318	1317	3.89
1/26/02	Redwood Falls	A	792B	6.00	40.6	42	101	1338	1339	2.38
1/26/02	Redwood Falls	A	862B	8.00	40.8	45	103	1350	1349	4.49
1/26/02	Redwood Falls	A	871B	5.00	40.9	41	99	1342	1343	0.83

[a] B represents a deer captured during January 2002.

Appendix C. Mortality for radiocollared female white-tailed deer in southwest Minnesota, 2001-02..

Capture location	Age at Capture[a]	Date of Capture	Cause of Death	Age at Death (years)	Date of Death
Redwood Falls	Fawn	1/24/01	Predation[b]	0.5	2/13/01
Walnut Grove	Fawn	1/23/01	Bacterial infection	0.5	2/19/01
Lake Benton	Adult	1/22/01	Vehicle[b]	Unknown	3/6/01
Walnut Grove	Adult	1/24/01	Train	4.5	3/13/01
Redwood Falls	Adult	1/24/01	Unknown	Unknown	4/17/01
Lake Benton	Adult	1/22/01	Predation	2.5	10/16/01
Walnut Grove	Fawn	1/23/01	Hunting	1.5	11/3/01
Lake Benton	Adult	1/22/01	Hunting	Unknown	11/3/01
Redwood Falls	Adult	1/24/01	Hunting	Unknown	11/3/01
Redwood Falls	Adult	1/24/01	Hunting	8.5	11/3/01
Walnut Grove	Fawn	1/23/01	Hunting	1.5	11/4/01
Redwood Falls	Adult	1/24/01	Hunting	6.5	11/4/01
Redwood Falls	Adult	1/24/01	Vehicle	4.5	11/21/01
Redwood Falls	Adult	1/24/01	Vehicle	3.5	12/3/01
Walnut Grove	Fawn	1/23/01	Vehicle	1.5	12/4/01
Redwood Falls	Fawn	1/26/02	Capture related[b]	0.5	1/30/02
Redwood Falls	Adult	1/26/02	Unknown	Unknown	4/11/02

[a] Fawns were ~8 months old at capture and adults were >1 year old at capture.
[b] Deer mortality may have been capture related and was censored from study.

Appendix D. Capture data for white-tailed deer neonates in southwest Minnesota, spring 2001.

Radiocollar frequency	Date of Capture	Sex	Handling Time (min.)	Estimated Age (± 3 days)
760	5/22/2001	F	2	1
750	5/25/2001	M	5	1
820	5/25/2001	F	3	1
960	5/29/2001	F	2	3
880	5/29/2001	F	3	1
800	6/01/2001	F	3	2
940	6/01/2001	M	3	1
810	6/01/2001	F	3	2
770	6/01/2001	M	3	5
780	6/05/2001	F	2	2
870	6/05/2001	M	2	4
920	6/06/2001	F	2	2
890	6/07/2001	F	3	6
850	6/07/2001	M	3	8
910	6/07/2001	F	2	9
760	6/07/2001	M	2	13
900	6/07/2001	F	2	3
790	6/07/2001	M	5	5
930	6/09/2001	M	1	Unknown
860	6/09/2001	M	1	3
840	6/11/2001	F	2	Unknown

Appendix E. Capture data for white-tailed deer neonates in southwest Minnesota, spring 2002.

Radiocollar frequency	Date of Capture	Sex	Handling Time (min.)	Estimated Age (± 3 days)
270	5/23/02	M	3	2
050	5/25/02	F	5	8
180	5/25/02	M	1	4
070	5/28/02	M	4	7
130	5/29/02	M	6	3
799	5/30/02	M	4	8
768	6/1/02	M	6	3
160	6/1/02	F	1	Unknown
859	6/1/02	F	5	6
930	6/3/02	F	7	1
749	6/4/02	F	3	6
779	6/5/02	F	6	4
910	6/6/02	F	4	13
110	6/6/02	M	2	Unknown
889	6/7/02	M	6	8
940	6/7/02	F	4	10
210	6/7/02	F	6	7
789	6/8/02	F	6	5

Appendix F. Mortality for radiocollered white-tailed deer neonates in southwest Minnesota, summer 2001-02.

Sex	Year	Capture Date	Cause of mortality	Mortality date
Female	2001	5/22/01	Starvation[a]	5/25/01
Female	2001	6/1/01	Vehicle collision	7/29/01
Female	2002	5/25/02	Predation	6/2/02
Male	2002	6/1/02	Starvation[a]	6/4/02
Male	2002	5/28/02	Disease	6/12/02
Female	2002	6/5/02	Predation	6/15/02
Female	2002	6/7/02	Predation	6/23/02
Male	2002	6/6/02	Predation	8/4/02

[a] Fawn will be censored from study.

Appendix G. Movement for individual radiocollared female white-tailed deer in southwest Minnesota, 2001.

Deer ID	Study Site	Winter 50% Home Range (ha)	Winter 95% Home Range (ha)	Summer 50% Home Range (ha)	Summer 95% Home Range (ha)	Spring Movement (km)	Spring Dispersal (km)	Spring Migration (km)	Fall Movement (km)	Fall Migration (km)
111	RF			22.4	293.3	16.3		16.3	14.5	14.5
054	RF			37.7	88.9	0.0			0.0	
171	RF			20.6	168.1	10.7		10.7		
232	RF			43.9	212.5	1.6		1.6	1.6	1.6
289	RF	9.1	41.8	16.8	116.1	22.2		22.2		
352	RF			12.3	64.0	13.8		13.8		
410	RF			25.8	174.0	4.6		4.6	3.0	3.0
470	RF			38.0	297.0	22.6		22.6		
531	RF			33.3	170.5	0.0			0.0	
591	RF					205.0	205.0			
631	RF					1.7		1.7		
662	RF			22.1	164.3	0.0			0.0	
689	RF			21.4	116.4	23.3		23.3	23.3	23.3
722	RF			30.9	163.4	0.0			0.0	
750	RF			99.8	541.6	4.6		4.6	0.0	
782	RF					46.0.	46.0			
811	RF			31.5	151.5	0.0			0.0	
841	RF			26.3	155.6	3.1		3.1	13.4	13.4
901	RF									
032	WG									
091	WG			106.8	593.6	15.1		15.1	13.7	13.7
148	WG					4.0		4.0		
210	WG			14.6	187.7	3.2		3.2	0.0	
271	WG	89.0	423.8	32.1	232.0	30.8		30.8	29.9	29.9
331	WG			43.4	400.1	4.5		4.5	0	
390	WG					5.4		5.4	4.4	4.4
449	WG			68.2	268.3	2.8		2.8	0.0	
510	WG			59.0	630.1	0.0			0.0	
571	WG			18.4	136.0	3.7		3.7	0.0	
622	WG			18.0	208.4	8.2		8.2	6.2	6.2
653	WG			20.3	115.9	17.5		17.5	17.5	17.5
680	WG									
710	WG			22.4	180.9	5.1		5.1	5.1	5.1
741	WG			12.1	77.8	3.1		3.1	0.0	
803	WG					4.6		4.6		
832	WG			14.2	134.7	0.0				
862	WG			48.7	185.0	15.7	15.7		30.4	30.4
890	WG			60.1	371.4	1.7		1.7	1.9	1.9
881	LB			12.5	81.7	0.0			0.0	
853	LB			61.0	494.1	13.6		13.6	13.3	13.3
821	LB			58.8	314.6	4.7		4.7	0.0	
790	LB							.		
761	LB			22.3	182.9	7.1		7.1	7.1	7.1
731	LB			23.3	193.4	7.0		7.0	7.2	7.2
702	LB									
672	LB			14.7	112.1	2.6		2.6	0.0	
643	LB			21.0	227.5	4.6		4.6	4.6	4.6
611	LB			40.6	211.3	10.1		10.1	11.0	11.0
551	LB			40.8	285.3	2.4		2.4		

491	LB	28.2	182.6	13.4		13.4	13.4	13.4
430	LB	16.1	116.7	3.8		3.8	0.0	
372	LB			18.7	18.7		5.4	5.4
309	LB	16.2	163.2	0.0			0.0	
250	LB	54.9	382.5	10.3		10.3	8.0	8.0
193	LB	33.1	468.9	11.4		11.4		
131	LB	10.5	97.8	11.2		11.2	11.4	11.4
072	LB	202.7	1277.7	11.9		11.9	12.0	12.0
011	LB	46.1	309.1	2.3		2.3	0.0	

Blank cell represents “no data”.

Appendix H. Movement for individual radiocollared female white-tailed deer in southwest Minnesota, 2002.

Study Site	Deer ID	Winter[b] 50% Home Range (ha)	Winter[b] 95% Home Range (ha)	Summer 50% Home Range (ha)	Summer 95% Home Range (ha)	Spring Movement (km)	Spring Migration (km)
RF	111	20.7	85.3	28.2	267.2	14.4	14.4
RF	054	40.6	323.7	13.3	74.6	0.0	
RF	149B[a]	41.5	242.8	19.5	124.3	0.0	
RF	171B[a]	74.0	208.2				
RF	391B[a]			16.8	100.5	18.2	18.2
RF	410			14.4	92.5	3.3	3.3
RF	512B[a]	60.6	350.5			0.0	
RF	531	17.3	167.1	9.5	87.6	0.0	
RF	591	57.2	347.8			3.9	3.9
RF	662	71.6	576.0	34.4	228.3	0.0	
RF	680B[a]			56.8	412.0	0.0	
RF	689	104.4	596.0	15.1	99.4	22.4	22.4
RF	702B[a]					11.9	11.9
RF	722	25.8	268.6	12.9	119.6	0.0	
RF	750	151.3	1053.0	22.5	180.3	0.0	
RF	770B[a]			19.5	197.3	0.0	
RF	782	18.2	136.4			0.0	
RF	811	61.6	387.8	13.1	71.5	0.0	
RF	841			12.8	126.7	0.0	
RF	862B[a]			79.6	496.0	3.5	3.5
RF	871B[a]			16.4	157.2	12.2	12.2
WG	091	207.6	1007.0	34.8	280.2	13.2	13.2
WG	210	76.2	524.5	11.4	57.3	0.0	
WG	271	91.6	902.3	17.2	107.5	29.9	29.9
WG	331	76.0	552.2	17.0	182.2	0.0	
WG	390			60.7	346.7	0.0	
WG	449	103.8	552.6	16.7	96.0	0.0	
WG	510						
WG	571	17.9	158.0	3.9	42.9	0.0	
WG	622	217.4	1014.3	58.8	318.4	6.4	6.4
WG	653	13.3	72.5	21.8	223.0	17.4	17.4
WG	710	151.0	1016.8	30.8	219.3	0.0	
WG	741	14.7	72.1	12.7	52.5	0.0	
WG	890	96.9	498.0	27.9	193.8	2.0	2.0
LB	901B[a]					19.3	19.3
LB	881	23.8	191.5	9.7	59.4	0.0	
LB	868B[a]			96.7	574.1	19.4	19.4
LB	853	336.7	1803.7	19.7	150.1	13.3	13.3
LB	832B[a]					4.3	4.3
LB	821	211.7	1866.7			0.0	
LB	803B[a]			79.0	327.0	6.8	6.8
LB	761	15.6	209.5	43.3	187.8	7.2	7.2
LB	731	71.6	456.6	33.8	255.2	7.6	7.6
LB	672	73.0	526.6	25.4	208.8	0.0	
LB	643	12.8	133.3	38.4	204.5	4.5	4.5

LB	611	15.5	88.8	19.2	248.6	11.4	11.4
LB	551B[a]			58.9	242.7	3.2	3.2
LB	491			18.5	128.9	13.3	13.3
LB	430			19.2	187.4	3.0	3.0
LB	372	100.9	475.1	77.6	262.7	5.8	5.8
LB	352B[a]					15.6	15.6
LB	309			69.5	457.6	5.8	5.8
LB	250	231.7	1629.6	19.6	156.0	8.2	8.2
LB	131			4.6	47.1	11.5	11.5
LB	072			47.6	345.9	11.9	11.9
LB	032B[a]			34.1	267.6	16.7	16.7
LB	011	28.3	216.5	21.9	125.4	0.0	

[a] B represents a deer captured during January 2002.
[b] Home range calculated using locations gathered during winter season 2001-2002.
Blank cell represents “no data”.