South Dakota State University
Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

Electronic Theses and Dissertations

2011

Movement Patterns, Survival, and Sightability of White-Tailed Deer (Odocoileus virginianus) in Eastern South Dakota

Kevin A. Robling

MOVEMENT PATTERNS, SURVIVAL, AND SIGHTABILITY OF WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS)* IN EASTERN SOUTH DAKOTA

BY

KEVIN A. ROBLING

A thesis submitted in partial fulfillment of the requirements for the

Masters of Science

Major in Wildlife and Fisheries Sciences

Wildlife Specialization

South Dakota State University

2011

MOVEMENT PATTERNS, SURVIVAL, AND SIGHTABILITY OF WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS)* IN EASTERN SOUTH DAKOTA

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

Dr. Jonathan A. Jenks — Date
Thesis Advisor

Dr. David W. Willis — Date
Head, Wildlife and Fisheries Sciences

ACKNOWLEDGEMENTS

I would like to thank my major advisor, Dr. Jonathan A. Jenks for his wisdom, advice and encouragement throughout this study. Jon, I thank you for all you have taught me and for granting me the freedom to think independently throughout my time at South Dakota State University. It has definitely been a privilege working with you and I look forward to future collaborative research efforts. I will always respect you a great deal on a professional and personal level.

I could not have completed this research without the support and cooperation from numerous people. Dr. Troy Grovenburg, I thank you for your guidance and patience throughout this study. Your expertise and advice with statistical procedures, SAS code, Program Mark, Program R, ArcMap and ArcView were priceless and I do not know what I would have done without you. You have been a great friend and mentor. Dr. Robert Klaver, thank you for providing research direction and assistance with the many software programs our field has to offer. I thank Jason Nordmann for his volunteer assistance during capture. Jason, I am very grateful for your comical relieve, elaborate trapping ideas, and working fingers during extremely cold temperatures. I thank Trenton Haffley for his guidance and help in answering research questions pertaining to study design and methodology. I also need to thank Dave Gilbert for providing aerial support throughout the study. Dave, you are an excellent pilot and I am fortunate to have worked with you. Special thanks goes out to Eric Schroeder, John Bender, Kevin Zobel and the students from Large Mammal Ecology class who assisted with deer capture.

I thank South Dakota Game, Fish and Parks personnel for their continued support and interest in my project, especially Scott Lindgren, Jeff Lautenslager and Loren Vande Stroet. Scott, I cannot thank you enough for everything you have done for me throughout this study. Your inquisitive ideas and advice have benefitted this project in so many ways. You have been a great mentor and friend and I truly appreciate your passion for whitetails. I thank conservation officer Jeff Lautenslager for his friendship and the many hours he spent in the air observing deer. Jeff, the memories we made in Clark will never be forgotten. Loren, thanks for taking the time out of your hectic schedule to help with this project. You provided much needed comical relieve and a keen eye during aerial surveys.

Thanks to all of the landowners in Clark County; especially Dean, Jerry and Ramona Kirkeby, Merritt Seefeldt, John Arthur, Tom Wookey, Gary Holdgrafer, Rick Sundvold, and the Double P Ranch, who gave me access to their land throughout the entire study. Without your generosity and cooperation, this project would not have been possible. A special thanks goes out to Dean and Ramona Kirkeby for providing me a place to live, ranching education, plowing roads and pulling me out while tracking, shop repair work, many warm cups of coffee, and the best home cooking I have ever experienced.

Finally, and most importantly, I thank my family for their continued support and encouragement while I pursued my dreams. Mom and Dad, you have been my rock and my foundation and words cannot express my gratitude. I love you both very much and cannot thank you enough for everything you have done for me throughout my life. To my four-legged best friends Boone and the late Trigger, for their companionship and unconditional love. Lastly, I need to thank Holly Theede for being there for me throughout my study. Holly, the long phone calls, numerous visits and endless support and encouragement you have provided has been priceless. I am very excited to see what the future has in store for us both.

Funding for this project was provided by the Federal Aid to Wildlife Restoration, Project W-75-R-145, No. 7534, administered through South Dakota Department of Game, Fish and Parks; the National Collegiate Athletic Association post graduate scholarship program, and the Department of Wildlife and Fisheries Sciences at South Dakota State University.

ABSTRACT

MOVEMENT PATTERNS, SURVIVAL, AND SIGHTABILITY OF WHITE-TAILED DEER IN EASTERN SOUTH DAKOTA

Kevin Robling

2011

Limited information is available on white-tailed deer (*Odocoileus virginianus*) movements, survival, density, and resource selection in the Prairie Pothole Region of South Dakota where semi-permanent wetland densities are relatively high. Primary objectives of this study were to develop a sightability model for aerial surveying and document seasonal movement patterns and survival rates for white-tailed deer in this region. Secondary objectives were to calculate seasonal home ranges, daily and seasonal movements relative to management unit boundaries, determine cause specific mortality, and evaluate summer and winter resource use and selection. From February 2009 – February 2010, 43 adult female white-tailed deer along with 5 adult male white-tailed deer were monitored for survival and movements using radio telemetry. An additional 20 deer also were captured and ear-tagged. Capture methods included helicopter net guns and the use of Clover traps. A total of 6,877 locations was collected, with a mean 95% error ellipse of 1.8 ha. We documented a total of 55 seasonal movements during 4 migration periods. Snow depth and temperature were the primary causes of seasonal migration. Mean migration distance between seasonal home ranges was 4.76 km (SE=

0.38). A total of 119 individual home ranges was calculated during 4 periods of seasonal use. Mean 95% home range size was 2.94 km^2 (*n*=58, SE= 0.38) during winter and 1.49 km^2 (*n*=61, SE=0.10) during summer. No deer crossed management unit boundaries and no dispersals were documented throughout the study. Movement and migration distances were likely reduced because of the juxtaposition of suitable habitat (i.e., wetlands and CRP grasslands) in the Clark County area. During this study, 17 deer died, and overall (24 month) survival rate was 0.55 (SE=0.08, *n*=43). Annual survival rates of female deer during 2009 and 2010 were 0.78 (SE = 0.08, *n* = 26) and 0.70 (SE = 0.08, *n*= 37), respectively. Seasonal survival rates for post-hunt, pre-hunt, and hunting seasons during 2009 and 2010 were 0.96 (SE= 0.04, *n*=26), 1.00 (SE < 0.001, *n*= 25), 0.84 (SE = 0.07, *n*= 34) and 0.94 (SE = 0.04, *n*= 37), 1.00 (SE < 0.001, *n*= 36), 0.72 (SE = 0.07, *n*= 36), respectively. Survival was predominately dependent on hunting, which was responsible for 64.5% of all mortalities. Liberal antlerless deer-tag numbers, lengthy hunting seasons, and high hunter densities likely influenced human related mortality of white-tailed deer in this region. Habitat categories encompassing 61 summer and 58 winter home ranges of 42 radiocollared female white-tailed deer were mapped during summer 2009 (*n*=25) and 2010 (*n*=36), and winter 2009 (*n*=22) and 2010 (*n*=36). We collected 4,688 summer locations and 1,826 winter locations via radio telemetry. Habitat use differed slightly between seasons with CRP grasslands, standing corn, and wetlands being used the most throughout summer home ranges and CRP grasslands, trees, and wetlands being used the most during winter. Overall, wetland habitat was used the most by deer in the Clark County area, and provided essential thermal and escape cover;

however, deer use of wetlands did not exceed availability. We evaluated winter and summer resource selection using design II and III analyses. Analysis using design II demonstrated that trees ($\hat{w} = 3.81$) were selected with higher probability ($P<0.10$) when compared to all other habitats available for both winter and summer. During the winter, CRP grasslands ($\hat{w} = 1.45$) and standing corn ($\hat{w} = 2.89$) also were selected by deer. Design III analysis indicated that extensive variation existed between animals and the proportions of habitat categories found within individual home ranges; however, the model using all animals indicated that trees ($\hat{w} = 2.67$) were selected with higher probability then other habitats ($P<0.10$). In the spring of 2009 and 2010, a total of seven sightability flights were conducted in late April and early May when potential color differences between sun-bleached deer and spring green-up were present. In the winter of 2010 and 2011, a total of 8 flights were conducted in January and February when 100% snow cover was present and deer were in large winter herds. Several variables were collected during the flights including; group size, activity, habitat, and canopy cover. Deer were sighted in the winter at a rate of 84.4% (146/173) and spring sightability rate was 54.6% (88/161). Logistic regression analysis indicated that visibility was significantly influenced by group size and canopy cover for both models. The winter model estimated deer sightability as $\mu = 3.064 + 0.044$ (group size) – 1.13 (canopy cover) and the spring model estimated deer sightability as $\mu = 2.297 + 0.252$ (group size) – 1.10 (canopy cover). These models will assist South Dakota Game, Fish and Parks in estimating population size of white-tailed deer in agricultural dominated landscapes throughout eastern South Dakota.

TABLE OF CONTENTS

CHAPTER 3: SURVIVAL OF WHITE-TAILED DEER IN EASTERN SOUTH DAKOTA

CHAPTER 5: SIGHTABILITY OF WHITE-TAILED DEER IN EASTERN SOUTH DAKOTA

AUTHORS NOTE: The verbiage for the text (We versus I) was selected to articulate the point that research endeavors are rarely a singular effort from data collection to synthesis of the data to printed form.

LIST OF TABLES

CHAPTER 5

LIST OF FIGURES

CHAPTER 2

CHAPTER 3

CHAPTER 5

LIST OF APPENDICES

CHAPTER 1: GENERAL INTRODUCTION

Knowledge of white-tailed deer (*Odocoileus virginianus)* population dynamics is essential for population management. Wildlife managers strive to maintain landowner tolerance and meet hunter demands for white-tailed deer. The ultimate goal of management is to meet the needs of all stakeholders interested and provide the most opportunity possible. For this reason, managers cannot rely upon personal opinions and theory to adequately manage the resource (McCullough 1987). Empirical data and sound biological evidence must be collected to justify harvest and how the population is managed. White-tailed deer are the most sought after big game species in North America and hold much economic value (McCullough 1987). White-tailed deer also carry much aesthetic and biological value throughout their range and maintaining these values for future generations is essential. Thus, it is vitally important to conduct studies that monitor deer population dynamics to improve overall deer management and sustain this valuable resource across its geographic range.

Throughout history, white-tailed deer have proved to be robust survivors and have shown how quickly they can adapt to their surroundings. By the late 1800's, deer were nearly eradicated as a result of advancing settlement, unregulated hunting, and intensified farming practices (Cook 1945, Kernohan et al. 2002). By the early 1900's white-tailed deer numbers in North America dropped to an estimated all time low of 500,000 animals (Cook and Dagget 1995, Hubbard et al. 2000). During the mid 1900's, land use practices changed, harvest became regulated, and the birth of conservation programs provided white-tailed deer with better habitat and higher-quality forage, allowing the species to recover (Cook 1945, Kernohan et al. 2002). Today, white-tailed deer numbers in North America exceed 27 million animals (Knapp 2001) and the species thrives in high densities in the agricultural regions of the Midwest and Northern Great Plains (Naugle et al. 1996, Burris 2005, Grovenburg et al. 2009).

Eastern South Dakota serves as suitable habitat within the Northern Great Plains region and has an abundant white-tailed deer population despite limited patches of permanent cover. Currently, deer populations in eastern South Dakota are managed through the use of political boundaries and harvest quotas are based on management units (counties). The South Dakota Department of Game, Fish and Parks utilize population models to determine the number of licenses (tags) distributed for legal harvest annually that will maintain populations within management goals. Models incorporate several variables including; population size estimates, annual adult survival rates, annual fawn survival rates, sex ratios, recruitment estimates, and age structure data. Most data used for modeling are collected through hunter surveys and observational data obtained through fall deer classification surveys (Burris 2005, South Dakota Department of Game, Fish and Parks 2011). These models serve as the primary tool for implementing management strategies within the agency, thus, emphasizing the importance of determining unknown variables. Primary objectives of this study were to: 1) Develop sightability models for aerial surveying, 2) Document seasonal movement patterns and survival rates for white-tailed deer in this region. Secondary objectives were to: 1) Calculate seasonal home ranges, daily and seasonal movements relative to management unit boundaries, 2) Determine cause specific mortality, 3) Evaluate summer and winter resource use and selection.

LITERATURE CITED

Burris, B. M. 2005. Seasonal movements of white-tailed deer in eastern South Dakota and southwestern Minnesota relative to traditional ranges and management unit boundaries. M. S. Thesis, South Dakota State University, Brookings, USA.

Cook, F. W. 1945. White-tailed deer in the Great Plains region. Journal of Wildlife Management 9:237-242.

Cook, K. E., and P. M. Daggett. 1995. Highway roadkill: associated issues of safety and impacts on highway ecotones. Task force on natural resources, Transportation Research Board. National Research Council, Washington, D.C., USA.

Grovenburg, T. W., J. A. Jenks, R. W. Klaver, C. C. Swanson, C. N. Jacques, and D. Todey. 2009. Seasonal movements and home ranges of white-tailed deer in north-central South Dakota. Canadian Journal of Zoology 87:876-885.

Hubbard, M. W., B. J. Danielson, and R. A. Schmitz. 2000. Factors influencing the location of deer-vehicle accidents in Iowa. Journal of Wildlife Management 64:707-713.

Kernohan, B. J., J. A. Jenks, and D. E. Naugle. 2002. Localized movements and site-fidelity of white-tailed deer in the Northern Great Plains. Prairie Naturalist 26:293-300.

Knapp, K. 2001. Midwest deer-vehicle crash facts. Deer-Vehicle Crash Information Clearinghouse. University of Wisconsin, Madison, USA.

McCullough, D. R. 1987. The theory and Management of *Odocoileus* populations. Pages535-549 *in* C. M. Wemmer, editor, Biology and Management of the Cervidae.

Naugle, D. E., J. A. Jenks, and B. J. Kernohan. 1996. Use of thermal infrared sensing to determine density of white-tailed deer. Wildlife Society Bulletin 24:37-43.

South Dakota Department of Game, Fish and Parks. 2011. 2010 Big game harvest projections. South Dakota Game Report No 2011-05. Division of Wildlife, South Dakota Department of Game, Fish and Parks, Pierre, USA.

CHAPTER 2: SEASONAL MOVEMENTS AND HOMERANGE SIZE OF WHITE-TAILED DEER IN THE PRIAIRE POTHOLE REGION OF EASTERN SOUTH DAKOTA

ABSTRACT Limited information is available on white-tailed deer (*Odocoileus virginianus*) movements, both migratory and daily movement patterns, in the Prairie Pothole Region where semi-permanent wetland densities are relatively high. The purpose of this study was to document seasonal movements, daily movements, and 50 and 95% home ranges in relation to management unit boundaries. From February 2009 – February 2010, 30 adult (>1.5 years) and 13 yearling (8-18 months) female white-tailed deer were monitored for survival and movements using radio telemetry. Capture methods included helicopter net guns and the use of Clover traps. A total of 6,877 locations was collected, with a mean 95% error ellipse of 1.8 ha. We documented a total of 56 seasonal movements during 4 migration periods. Snow depth and temperature were the primary causes of seasonal migration. Mean migration distance between seasonal home ranges was 4.76 km (SE= 0.38). A total of 119 individual home ranges was calculated during 4 periods of seasonal use. Pooled mean 95% home range size was 2.94 km^2 (SE = 0.38, n = 58) during winter and 1.49 km^2 (SE = 0.10, n =61) during summer. No deer crossed management unit boundaries (i.e. county lines) and no dispersals were documented throughout this study. Rare movements across county lines will have limited effects on pre-harvest counts and population models.

INTRODUCTION

Movement patterns and home range size of white-tailed deer have been studied thoroughly throughout eastern South Dakota and southwestern Minnesota (Sparrowe and Springer 1970, Kernohan 1994, Brinkman 2003, Burris 2005, Swanson 2005, Grovenburg et al. 2009). Understanding these movement strategies could be important relative to current and future management unit boundaries. Deer in this region have been documented to exhibit three patterns of movement: short distance, dispersal, and seasonal migration (Kernohan et al. 1994, Grovenburg et al. 2009). Short-distance movements result in no significant change in home range boundaries and are usually related to food resources. These types of movements typically occur in areas where food availability is not limited and where seasonal weather extremes are milder (Marchinton and Hirth 1984, Gaudette and Stauffer 1988, Sabine et al. 2002, Grovenburg et al. 2009).

Dispersal movements have been documented in white-tailed deer in the Northern Great Plains and are categorized as permanent, long-distance movements away from previously established home ranges to create a new home range (Kernohan et al. 1994, VerCauteren and Hygnstrom 1998, Brinkman 2003, Burris 2005, Grovenburg et al. 2009). Burris (2005) documented female white-tailed deer dispersals of 130.1, 134.0 and 166.5 km in eastern South Dakota. Determining the rate of dispersal is important in understanding how the role of emigration and immigration affect population dynamics of the species (Rosenberry et al. 1999). These long-distance dispersals generally cross county and state lines and dispersing animals can contribute to the spread of disease and invasive species, and affect gene flow. However, dispersal rates and distances are difficult to measure and thus, managers typically assume immigration and emigration are equivalent (Johnson 1994, Rosenberry et al. 1999). Rational for why white-tailed deer demonstrate such behaviors remains unknown (Bowman 2003, Grovenburg 2007).

Seasonal migrations are among the most common types of movement displayed by white-tailed deer in the northern portions of their range (Ozoga and Gysel 1972, Nelson 1998, Van Deelen et al. 1998, Swanson 2005, Grovenburg et al. 2009). Distances between summer and winter ranges usually exceed 10 km and mean migration distances of 10.1 km (Brinkman 2003), 10.1 km (Burris 2005), 14.6 km (Swanson 2005), and 19.4 km (Grovenburg et al. 2009) have been documented in eastern South Dakota and western Minnesota. Long distances between seasonal home ranges represent the potential for deer moving across management unit boundaries, which could affect population models and pre-harvest counts (Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009). Understanding timing and cause of these movements allows managers to decide if movement patterns should be incorporated into population models or if deer management units should be based on physiographic regions rather than county lines (Sparrowe and Springer 1970, Burris 2005, Grovenberg et al. 2009).

Migrations from summer to winter ranges throughout the Northern Great Plains are influenced by snow depth, cold temperatures, photoperiod, and changes in vegetative cover due to fluctuating snow depths (Nelson 1998, Brinkman et al. 2005, Swanson 2005, Burris 2005, Grovenburg et al. 2009). Areas where winter herds are present are characterized by elaborate trail systems that lead to different food resources and thermal cover (Nelson and Mech 1981). Previous studies indicate that these movements generally occur in November and December depending on weather conditions (Sparrowe and Springer 1970, Brinkman 2003, Burris 2005, Swanson 2005, Grovenburg 2007). Spring movements, in contrast, usually occur between March and April in the northern regions of the white-tailed deer range and are typically influenced by rising temperatures, decreasing snow cover, and newly available spring forage (Sparrowe and Springer 1970, Brinkman 2003, Swanson 2005, Burris 2005, Grovenburg et al. 2009).

Although, white-tailed deer movements and seasonal home range sizes have been documented in eastern South Dakota (Sparrowe and Springer 1970, Kernohan et al. 1994, Burris 2005, Grovenburg et al. 2009), limited information exists on movements and home range size where wetlands cover much of the landscape. Primary objectives of this study were to document seasonal movement patterns of white-tailed deer in the Prairie Pothole Region where wetland densities are high ($\geq$ 20% land cover; Smith et al. 2002). Secondary objectives were to calculate seasonal home ranges for deer in this area. We hypothesized (1) that average seasonal movements between ranges would be similar to those documented by Burris (2005) and Grovenburg et al. (2009), which were between 10.1 km and 19.4 km and (2) seasonal home range sizes would be similar to those documented by Kernohan et al. (1994), Brinkman et al. (2005) Burris (2005), and Grovenburg et al. (2009), which ranged between 1.04 km^2 – 10.1 km^2.

STUDY AREA

We studied adult female white-tailed deer from January 2009 to February 2011 in Clark County, South Dakota (Figure 1), which comprised a study site area of 1,294 km^2. Mean annual (30-yr) precipitation was 56.2 cm and mean (30-yr) monthly temperature ranged from -11.9^{o} C to 21.8^{o} C (South Dakota Office of Climatology 2011). Clark County is located in the Northern Glaciated Plains level III ecoregion (Bryce et al. 1998) and lies in the Prairie Pothole Region (Johnson et al. 1997). Soils of the region are composed of glacial till and terrain is typically flat to gently rolling and intermixed with numerous semi-permanent, temporary, and seasonal wetlands of glacial origin (Bryce et al. 1998, Johnson et al. 1997). Soils are fertile and predominant land use in Clark County is agriculture with cultivated land and pasture/hay land comprising 45.2% and 19.0% of total land use, respectively (U.S. Geological Survey 2010). Wetlands comprised 11.6% of the county with grasslands accounting for another 11.0%, respectively, of the landscape (U.S. Geological Survey 2010). However, the 1,294 km^2 study area within Clark County was unique. Within this area, cultivated crops, including corn (*Zea mays*), soybeans (*Glycine max*), and wheat (*Triticum aestivum*) made up 48% of the landscape and pasture land made up 8% of the landscape. Wetlands and grasslands comprised 23% and 15% of the landscape, respectively. Woodland plantings and shelterbelts, and developed areas each comprised 3% of the area (Smith et al. 2002).

Native warm and cool season grasslands that were enrolled in the Conservation Reserve Program (CRP) was dominated by big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), western wheat grass (*Elymus smithii*), Indiangrass (*Sorghastrum nutans*), switch grass (*Panicum virgatum*), and smooth brome (*Bromus inermis*). Wetland vegetation was dominated by cattails (*Typha* spp.), sedges (*Carex* spp.), rushes (*Juncus* spp.), reed canary grass (*Phalaris arundinacea*), prairie cordgrass (*Spartina pectinata*), and common reed (*Phragmites australis*). Woodlands and shelterbelts were comprised of American elm (*Ulmus americana*), green ash (*Fraxinus pennslyvanica*), eastern cottonwood (*Populus deltoides*), boxelder (*Acer negundo*) and eastern red ceder (*Juniperus virginiana*: Johnson and Larson 1999).

Land ownership in the area was dominated by private land; however, a mixture of State Game Production Areas, Federal Waterfowl Production Areas and Walk-In Areas (Private land hunting access) did exist, allowing limited public hunting opportunities (South Dakota Department of Game, Fish and Parks 2010*b*).

METHODS

Capture and Handling

We captured white-tailed deer using modified Clover traps (Clover 1956) and helicopter net guns (Jacques et al. 2009) from 22 January to 15 February 2009 and from 7 January to 25 February 2010 at two capture sites in Clark County, South Dakota (Figure 1). We directed trapping and net gunning efforts towards adult females because they perform a significant function (i.e., reproduction) and normally dominate white-tailed deer harvest in eastern South Dakota (South Dakota Department of Game, Fish and Parks 2010*a*). We baited trapping sites with a combination of high quality alfalfa, shelled corn, and molasses. Concerns regarding animal welfare were addressed by checking traps daily at first light to minimize stress of the individual and prevent injury. Captured individuals were manually restrained and blindfolded to reduce stress.

Female white-tailed deer that we captured via helicopter net-gun were restrained, hobbled, and blindfolded by a crewmember that exited the helicopter after net-gunning occurred. Deer were then transported below the helicopter, in canvas transport bags, to crew members at the processing site. Once deer arrived at the processing site, we quickly removed them from the transport bags and monitored deer by recording rectal temperature as an index to physiological stress (DelGuidice et al. 2001). If temperatures exceeded 40 ^{o}C, we applied a mixture of ice water and isopropyl alcohol ventrally to the deer to reduce and stabilize body temperature. If temperature did not stabilize and continued to increase, we immediately released the deer (Grovenburg 2007). We recorded processing time and distance from the capture location to processing site for each individual.

We sexed and aged all captured deer as fawn (~8-10 months) or adult (≥1.5 years) based on tooth replacement and incisor wear (Severinghaus 1949, Severinghaus and Cheatum 1956). We ear-tagged all animals with metal and plastic ear-tags (Hasco Tag Company, Dayton, KY, USA) and fitted adult females with VHF (Very High Frequency) radiocollars (Advanced Telemetry Systems, Inc., Isanti, MN) that were equipped with mortality sensors (sensors activated if the collar remained still for 8 hours). Animals that we caught with the helicopter net gun were administered an intramuscular injection of a broad-spectrum antibiotic (i.e., penicillin). We examined overall physical condition of the captured animals and removed blindfolds and hobbles before animals were released. All methods described in this research was approved by the Institutional Animal Care and Use Committee (IACUC, Approval No. 08-A028) at South Dakota State University.

Monitoring Radio-collared Deer

We monitored all radio-collared deer 2-3 times weekly for survival and performed ground triangulation using a vehicle mounted "null-peak" antenna system (Brinkman et al. 2002). We took four to six directional bearings from established telemetry stations for each location. We used an electronic digital compass (C100 Compass Engine, KVH Industries, Inc., Middletown, RI, USA; Cox et al. 2002) that was connected to the mast of the null-peak antenna system to generate directional bearings; this unit had an estimated azimuth accuracy of +/-1^{o}, which we recalibrated every six months. We entered bearings into the LOCATE III computer program (Nams 2006) to estimate locations and error polygons. All locations were generated from a minimum of three azimuths; locations with 95% error ellipses ≥20 ha were excluded from analyses (Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2010). To ensure accurate home range estimates, animals were never located on successive days and were tracked at different times of the day, including nights, to maintain temporal independence (Kernohan et al. 1998). We excluded animals that experienced mortality ≤26 days post capture from analyses (Beringer et al. 1996).

Home range and Movement Analysis

We imported locations into ArcView (ESRI, Inc., Redlands, CA) and used the fixed kernel method using the Home Range Extension (HRE) (Rodgers and Carr 1998) to calculate 50% (core area) and 95% seasonal home ranges. We used least-squares cross-validation to estimate the smoothing parameter (LSCV; Seaman et al. 1999).

We calculated seasonal migration distance by measuring the straight-line distance between harmonic means of seasonal home ranges (Grovenburg et al. 2009). Deer were considered migratory if no overlap existed between seasonal home ranges (Burris 2005, Swanson 2005, Grovenburg et al. 2010). We calculated migration date as the mean date of departure between consecutive locations on separate seasonal ranges (Nelson 1995). We classified animals as obligate migrators if they migrated annually between seasonal home ranges and resided there until the following migratory period occurred (Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009). We classified deer as conditional or facultative migrators (Nelson 1995) if they failed to migrate during a documented migratory period or made several trips between seasonal home ranges and occupied that home range for <1 month (Brinkman et al. 2005). We classified deer as residents if they failed to migrate and had overlapping seasonal home ranges. Spring migration was classified as movement from winter to summer ranges and fall migration was classified as movement from summer to winter range. We used ANOVA to compare home range sizes and migration distances of radio-collared deer between years and seasons (Zar 1999).

We calculated deer winter severity index (DWSI; Brinkman et al. 2005) for the Clark County area during the winter of 2008-09 and 2009-10. We assigned one point for each day mean temperature was $\leq -7\,^{o}$C and an additional point for each day snow depth was $\geq$ 35.0 cm (Brinkman et al. 2005) during the months of October-April (National Climatic Data Center 2011).

RESULTS

We captured and radio-collared 30 adult (>1.5 years) and 13 yearling (8-18 months) female white-tailed deer during January-February 2009 (*n*=26; Appendix A) and January-February 2010 (*n*=17; Appendix B) at two sites in Clark County, South Dakota (Figure 1). We captured and ear-tagged an additional 20 deer (1 adult male, 1 yearling male, 9 male fawns, 9 female fawns; Appendix A, B) and radiocollared an additional five adult males (Appendix B). One capture related mortality occurred during helicopter net-gunning operations in 2009; a yearling female broke her right pelvis when netted from the helicopter and was euthanized at the processing site. An additional capture related mortality occurred during trapping operations in 2010; a female fawn was found dead in a trap and was transported to the Animal Disease Research and Diagnostic Laboratory at South Dakota State University (SDSU) where gross examination revealed a severe anteroventral abscessing pneumonia affecting the majority of lung lobes.

We captured 25 female white-tailed using helicopter net-gun operations during 8 hours of capture over two capture seasons (3.12 deer per hour). Mean handling time for radio-collared deer captured with the helicopter was 2.3 (SE=0.19) minutes. We captured 44 deer in 329 trap-nights while Clover trapping and overall capture success was 7.48 trap-nights/individual and 17.32 trap-nights/radio-collared individual. We recaptured 3 marked individuals during trapping operations (1 radio-collared adult female, 1 female fawn, 1 male fawn). We also captured two deer in one trap and released one animal without marking the individual. Mean handling time for radio-collared deer captured by Clover trapping was 4.3 (SE=0.21) minutes and mean handling time was 1.6 (SE=0.1) minutes for ear-tagged individuals.

We collected a total of 6,877 deer locations with a mean 95% error ellipse of 1.8 ha from January 2009-February 2011 in Clark County, South Dakota. We documented 56 seasonal movements (Appendix C, D) during four periods of migration; spring 2009, fall 2009, spring 2010, and fall 2010. We calculated 119 individual home ranges

(Appendix C, D) using a minimum of 20 locations during 4 periods of seasonal use; winter 2009, summer 2009, winter 2009-10, and summer 2010. We censored 5 deer with <20 locations from home range analyses because of mortality loss and insufficient locations were collected in the winter of 2009.

Deer Movements

During spring 2009, 12 (48%) deer migrated a mean distance of 4.82 km (SE=1.02, range=10.1 km; Table 1). Thirteen (52%) deer did not migrate during this period. Median departure date for 12 migrating individuals was 6 April and ranged from 17 March to 26 May. No deer crossed management unit boundaries or dispersed during this migratory period.

During fall 2009, 11 (50%) deer migrated a mean distance of 5.37 km (SE=0.73, range=9.05 km; Table 1). Eleven (50%) deer did not migrate and had overlapping seasonal home ranges. Median departure date for 11 migrating individuals was 2 January and ranged from 14 December to 29 January. No deer crossed management unit boundaries or dispersed during this time.

During spring 2010, 20 (54%) deer migrated a mean distance of 5.02 km (SE=0.61, range= 11.17 km; Table 1); seventeen (46%) deer did not migrate. Median departure date for 20 migrating individuals was 7 April and ranged from 18 March to 31 May. No dispersals were documented and no deer crossed management unit boundaries.

During fall 2010, 13 (43.3%) deer migrated a mean distance of 3.77 km (SE=0.74, range= 10.21 km; Table 1); seventeen (56.7%) deer did not exhibit migratory behavior. Mean migration date for 13 individuals was 23 December and ranged from 29 November to 17 January. Deer 151426 was monitored until 3 February 2011 and had not migrated at this time. No deer crossed management unit boundaries or dispersed during this time. Overall (2009-2011) mean migration distance of all deer that exhibited migratory behavior was 4.76 km (SE=0.38, *n*=56; Table 1).

Deer Winter Severity Index

Average DWSI for winter 2008-2009 and 2009-2010 (Figure 2) was 93.0 and 137.0, respectively, for Clark County. Seasonal migration was compared to temperature (^{o}C) and snow depth (cm) during spring 2009, fall 2009, spring 2010, and fall 2010 (Figure 3, 4). Deer migration in the Clark County area was influenced by temperature and snow depth (Figure 3, 4).

Home Ranges

We generated 58 winter and 61 summer home ranges during four periods: winter 2009 (*n* =22), summer 2009 (*n* = 25), winter 2010 (*n*= 36), and summer 2010 (*n*=36). We calculated individual home ranges using a minimum of 20 and a mean of 50.9 (SE=2.0, *n* = 119) locations.

In winter 2009, mean 50 and 95% home ranges were 1.07 (SE = 0.21, *n* = 22) and 4.60 km^2 (SE = 0.81, *n* = 22), respectively (Table 2). Adult white-tailed deer had mean 50 and 95% home ranges of 1.06 (SE = 0.27, *n* = 14) and 4.41 km^2 (SE = 0.98, *n* = 14), respectively. Yearling white-tailed deer had mean 50 and 95% home ranges of 1.1 (SE = 0.36, *n* = 8) and 4.93 km^2 (SE = 1.48, *n* = 8), respectively. Mean 50 and 95% home range size did not differ (*P* =0.929, *P* = 0.779) between adult and yearling deer.

In summer 2009, mean 50 and 95% home ranges were 0.32 (SE = 0.03, *n* = 25) and 1.6 km^2 (SE = 0.16, *n* = 25), respectively (Table 2). Adult white-tailed deer had mean 50 and 95 % home ranges of 0.30 (SE = 0.03, *n* = 15) and1.51 km^2 (SE = 0.17, *n* = 15), respectively. Yearling white-tailed deer had mean 50 and 95% home ranges of 0.35 (SE = 0.07, *n* = 10) and 1.74 km^2 (SE = 0.33, *n* = 10), respectively. Mean 50 and 95% home range size were similar (*P* = 0.606, *P* = 0.545) between adult and yearling deer.

In winter 2010, mean 50 and 95% home ranges were 0.44 (SE = 0.06, *n* = 36) and 1.92 km^2 (SE = 0.24, *n* = 36), respectively (Table 2). Mean 50 and 95% home ranges for adults were 0.41 (SE = 0.05, *n* = 32) and 1.85 km^2 (SE= 0.21, *n* = 32), respectively. Mean 50 and 95% home ranges for yearlings were 0.64 (SE = 0.44, *n* = 4) and 2.48 km^2 (SE = 1.55, *n* = 4), respectively. Mean 50 (*P*= 0.649) and 95% home ranges did not differ (*P* = 0.715) between adult and yearling deer.

In summer 2010, mean 50 and 95% home ranges (Table 2) were 0.31 (SE = 0.03, *n* = 36) and 1.41 km^2 (SE = 0.12, *n* = 36), respectively. Mean 50 and 95% home ranges for adults were 0.31 (SE = 0.03, *n* = 33) and 1.42 km^2 (SE= 0.13, *n* = 33), respectively. Mean 50 and 95% home ranges for yearlings were 0.28 (SE = 0.03, *n* =3) and 1.26 km^2 (SE = 0.09, *n* = 3), respectively. Mean 50 (*P*= 0.41) and 95% home ranges did not differ (*P* = 0.331) between adult and yearling deer.

Overall mean 50 and 95% home ranges during winter were 0.68 (SE = 0.10, *n* = 58) and 2.94 km^2 (SE = 0.38, *n* = 59), respectively. During summer, mean 50 and 95% home ranges were 0.31 (SE = 0.02, *n* =61) and 1.49 km^2 (SE = 0.10, *n* =61), respectively. Mean 50 and 95% home ranges were similar (*P* = 0.792, *P* = 0.338) between summer 2009 and 2010. Mean 50 and 95% home ranges differed (P = 0.008, P = 0.004) between winter 2009 and 2010.

DISCUSSION

Capture

Clover trapping capture success (13.4%) was comparable to that of Burris (2005; 12.8%); however, work done in east-central South Dakota by Naugle et al. (1995), and in Montana by Morgan and Dusek (1992), documented success rates of 35.9 and 41.0%. We postulate the lower success rate in this study was attributed to amount of various food resources available to deer. Throughout the study area, numerous plots of standing corn and soybeans were left unharvested for the purpose of feeding wildlife throughout the winter, which reduced interest in bait provided to deer in Clover traps. Capture success was dependent upon snow depth and temperature. Ninety one percent of captured individuals were captured when mean temperatures were $< -5\ ^{o}C$ and snow depth was > 30 cm. Overall, we trapped 44 white-tailed deer during two winter trapping seasons with one (2.3%) capture mortality. Capture related mortality for this study was ≤ other Clover trapping operations for white-tailed deer (7.3%, Burris 2005; 5.2%, Beringer et al. 1996; 5.4%, DelGiudice et al. 2005).

We captured 25 female white-tailed deer in 8 hours (3.12 deer per hour) of helicopter net-gunning operations with one (4%) capture mortality. Capture rates were comparable to those of Grovenburg (2007; 3.42 deer per hour) and Brinkman (2003; 3.12 deer per hour). Capture related mortality was similar to other helicopter net-gun operations (12.0%, Barrett et al. 1982; 2%, DelGiudice et al. 2001; 10%, Brinkman 2003;

2.4%, Grovenburg 2007; 1.4%, Jacques et al. 2009). No radio-collared deer captured during this study died < 26 days post-capture. Post-release mortality rates were minimized by limiting pursuit times during helicopter capture (Jacques et al. 2009) and processing animals as quickly as possible.

Seasonal Migration

We documented a shorter mean migration distance (4.76 km; Table 1) for female white-tailed deer in eastern South Dakota compared to recent work in eastern South Dakota (10.1 km; Burris 2005, 19.4 km; Grovenburg et al. 2009), western Minnesota (10.1 km; Brinkman et al. 2005; 14.6 km; Swanson 2005), and other northern regions of North America (15.6 km, Carlsen and Farmes 1957; 23.2 km, Sparrowe and Springer 1970; 13.8 km, Verme 1973; 20.7 km, Hoskinson and Mech 1976; 17.0 km, Nelson and Mech 1981; 11.0 km, Simon 1986; 13.0 km, Nixon et al. 1991; 15.7 km, Griffin et al. 1994; 23.8 km, Kernohan et al. 1994; 15.3 km, Lewis and Rongstad 1998; 6.8- 20.2 km, Sabine et al. 2002). Deer moved rapidly between seasonal ranges and time spent in transit was minimal (<1 week). In the Clark County region of eastern South Dakota, white-tailed deer may have demonstrated shorter migration distances because of the high abundance of suitable habitat (i.e., wetlands and CRP grasslands) available. Grovenburg et al. (2009) attributed the lack of suitable habitat (i.e., tree/forest cover) in east central South Dakota to longer migration distances. Long et al. (2005) documented that deer with minimal cover traveled farther distances to find suitable habitat. The Clark County area was punctuated with semi-permanent wetlands, which provided excellent thermal and escape cover (Sparrowe and Springer 1970, Kramlich 1985, Kernohan et al. 1996).

White-tailed deer also had unlimited food resources in the Clark County area because agricultural row crops were planted across 48% of the landscape. Tree cover in the Clark County area was similar to other study areas in western Minnesota and eastern South Dakota where migration distances were >10.1 km (Brinkman et al. 2005, Burris 2005, Swanson 2005). Variation in habitat characteristics (i.e., more wetlands) in the Clark County area likely explains the variation in white-tailed deer behavior.

White-tailed deer in the Clark County area exhibited mixed movement strategies, similar to those documented in earlier studies (Rongstad and Tester 1969, Sparrowe and Springer 1970, Nelson 1995, Sabine et al. 2002, Porter et al. 2004, Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009). Of 36 female white-tailed deer monitored ≥2 consecutive migration periods, 14 (38.9 %) were obligate migrators, 4 (11.1 %) conditional migrators and 18 (50.0 %) were residents. These percentages were similar to other studies conducted in eastern South Dakota (Burris 2005, Grovenburg et al. 2009). Grovenburg et al. (2011) noted that land-cover and landscape characteristics likely explained white-tailed deer migration behavior throughout the Northern Great Plains and indicated that increased forest cover increased the odds of a deer being a resident. Limited forested cover (< 3%) existed in the Clark County area; however, wetlands and CRP grasslands covered 38% of the landscape and these landscape characteristics may have explained why 50% of the deer in the Clark County area were residents.

No dispersals were documented in the Clark County area. Dispersals have been documented in the Midwest and Northern Great Plains (Sparrowe and Springer 1970, Nelson and Mech 1992, Kernohan et al. 1994, VerCauteren and Hygnstrom 1998, Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009). Previous documented dispersal rates in eastern South Dakota and western Minnesota ranged from 2.2 – 8.3% (Brinkman 2003, Burris 2005, Grovenburg et al. 2009). Burris (2005) and Grovenburg (2007) noted that limited forest habitat (< 2.3%) in the fragmented landscapes of the Northern Great Plains likely contributed to the dispersal behavior of white-tailed deer in eastern South Dakota and western Minnesota. Likewise, Long et al. (2005) determined that dispersal behavior in yearling male white-tailed deer was correlated with forest cover. Even though limited forested cover (< 3%) existed in the Clark County area, no dispersal behavior was documented; however, large amounts of suitable habitat (i.e., wetlands and CRP grasslands) may have reduced dispersal behavior in the Clark County area because patches of suitable habitat were present. Also, during our study, no fawns were radio-collared and this likely influenced dispersal rates because pregnant adult females commonly display aggression towards other deer, including previous offspring (Ozoga et al. 1982). This aggressive behavior forces previous offspring to establish new permanent ranges to avoid confrontation (Schwede et al. 1993), which may result in long-distance dispersal behavior. Occurrence of white-tailed deer dispersal behavior is an unknown phenomenon and continued research is needed to explain why some individuals within a population travel long distances while other populations express no such behavior (Bowman 2003).

Key factors influencing movement of white-tailed deer in northern regions are temperature and snow depth (Verme 1968, Ozoga and Gysel 1972, Drolet 1976, Nelson 1995, 1998, Sabine et al. 2002, Brinkman et al. 2005, Burris 2005, Grovenburg et al.

2009). To document effects of temperature and snow depth on seasonal movements we used a DWSI for white-tailed deer (Brinkman et al. 2005). Average DWSIs during winter 2008-09 (93.0; Figure 2) was less than winter 2009-10 (137.0; Figure 2), as winter severity indices > 100 are considered extreme (Verme 1968). Moderately severe winter weather potentially explains the low percentage (11.1%) of conditional migrators during this study. A decrease in the proportion of northern white-tailed deer remaining on summer ranges during severe winters has been well documented (Sparrowe and Springer 1970, Nelson 1995, Sabine et al. 2002) and Grovenburg et al. (2011) indicated that the odds of a white-tailed deer displaying migratory behavior increased with increasing winter severity indices. This behavior also was documented in the Clark County area and the majority of individuals that exhibited migratory behavior migrated each consecutive year and had high fidelity to their designated winter and summer ranges.

Median spring departure dates for 2009 (6 April, n= 12) and 2010 (7 April, n= 20) were similar to those documented by Nelson (19 March-4 May; 1995), Brinkman (8-18 April; 2003), Burris (24-25 March; 2005), Swanson (6-22 April; 2005), and Grovenburg (10-25 April; 2007). Spring migration in this study area coincided with increasing temperatures and decreasing snow depths. During spring 2009, 25% of migratory deer moved to summer ranges on 17 March 2009, when mean daily temperatures ranged from 4 to 7.5^{o} C over a three day period and snow depth decreased to 0 cm (Figure 3). On 1 April 2009, a snow event occurred and snow depth increased to 18 cm and mean temperatures remained below 0^{o} C over the next 9 days. On 13 April 2009, 33.3% of migratory deer moved when mean temperatures remained above 5^{o} C and all snow melted (Figure 3). During spring 2010, 35% of migratory deer moved to summer ranges between 18 March and 23 March 2009 when snow depth decreased to 0 cm and mean daily temperature increased to 6.5^{o} C by 23 March (Figure 3).

Median fall departure dates for 2009 (2 January, *n*= 12) and 2010 (22 December, *n*= 13) differed from those documented in the Northern Great Plains by Brinkman (28 November; 2003), Burris (28-29 November; 2005), Swanson (24-26 November; 2005) and Grovenburg (18-27 November; 2007). However, Sabine et al. (2002) and Nelson (1995) documented median fall departure dates ranging from (7 December-12 February) and (28 November-28 December). We speculate that later median fall departure dates occurring in the Clark County study area resulted from a combination of events including, but limited to, delayed crop harvest completion in 2009, high abundance of suitable habitat (i.e., wetlands), excessive hunting pressure towards pheasants (*Phasianus colchicus*) occurring on traditional winter ranges that disturbed white-tailed deer, and weather related events including fluctuations in daily temperatures and the occurrence of measurable snow.

Variation in harvest completion dates for soybeans and corn in northeastern South Dakota during 2009 and 2010 existed. Completion of 95% of the soybean harvest occurred on 29 November and 88% harvest completion for corn occurred on 4 January 2010, indicating 12% of the corn was left unharvested in northeastern South Dakota until spring. In 2010, dates for 95% completion of soybean and corn harvests were 23 October and 14 November, respectively (South Dakota Agriculture Statistics Service 2010). Later harvest completion dates in 2009 were attributed to unseasonably cool temperatures and excessive precipitation. Harvest delay may have caused deer to move later because abundant forage resources and cover were available. One individual that demonstrated unusually late migratory behavior from summer range migrated shortly after corn was harvested on 16 January 2010.

Another factor possibly attributing to the late departure of migratory deer in the Clark County area was the abundance of suitable habitat available within summer home ranges. Wetlands covered > 20% of the land in this study area and white-tailed deer utilized these wetland complexes regularly for escape and thermal cover. We postulate that once agricultural crops were harvested within summer ranges, deer utilized semi-permanent wetlands more and were not forced to move or migrate because cover was available. Late movements occurred when snow filled, once suitable, wetland complexes.

During this study, the regular deer firearms season had little impact on seasonal deer movement in the Clark County area. No deer migrated during the regular firearm season in 2009 (21 November- 6 December 2009) and 21% of migratory deer migrated during the 2010 season (20 November- 5 December 2010). However, daily movements of certain individuals were affected by hunters. This resulted in more deer located outside of their core home range area. Increased pheasant hunting pressure also initiated daily movements outside of core home range areas; however, deer normally returned to established ranges within a short period of time (i.e., <2 days). One explanation for later median departure dates is that deer in this region did not migrate to traditional wintering ranges until hunting pressure in those designated areas declined (VerCauteren and

Hygnstrom 1993). Many of these traditional winter ranges included public hunting land and land that was being managed by commercial hunting operations. Hunting pressure for pheasants and deer was intense between 10 November - 15 December and once snow depth exceeded 30 cm, hunting access was limited and hunting pressure decreased, possibly triggering seasonal movements of white-tailed deer in the Clark County study area.

Fall migration by most individuals in the Clark County area coincided with accumulation of snow and decreasing temperatures. During fall 2009, the first individual migrated on 14 December after mean daily temperatures decreased to -20^{o} C and a snow event increased snow depths to 10 cm. On 27 December 2009, 26 cm of snow fell, which increased mean snow depth in the area to > 43 cm. On 29 December 2009, 75% of migratory deer had moved to winter ranges (Figure 4). During fall 2010, the first individual migrated on 29 November 2010, after four consecutive days with mean daily temperatures < -10^{o} C. On 14 December 2010, snow depth increased to 15.5 cm and 43% of migratory deer had migrated to winter ranges. By 7 January 2011, snow depth increased to 66 cm and all migratory deer initiated migratory behavior.

During our study, no white-tailed deer crossed management unit boundaries during 4 migratory periods (i.e., spring 2009, fall 2009, spring 2010 and fall 2010). In addition, no resident deer crossed management unit boundaries. White-tailed deer in this study area demonstrated much shorter migration distances (4.76 km), which may explain high fidelity for the Clark County area. We speculate the high fidelity for the area may be explained by the interspersion of suitable patches of habitat throughout the Clark

County area. Long et al. (2005) hypothesized that white-tailed deer are forced to move long distances before finding suitable habitat in highly fragmented habitats; however, deer in our study did not move long distances and we speculate the presence of suitable habitat may have limited movements. Thus, resulting in no deer crossing management unit boundaries during our study.

Home Ranges

White-tailed deer home range size, within northern regions, is influenced by temperature, snow depth, population densities (Verme 1968, Ozoga and Gysel 1972, Nelson 1995, 1998, Sabine et al. 2002, Brinkman 2003, Burris 2005, Grovenburg et al. 2009), hunting pressure (Sparrowe and Springer 1970, Root et al. 1998, Naugle et al. 1997), habitat characteristics (Sparrowe and Springer 1970, Grovenburg 2007), and crop harvest (VerCauteren and Hygnstrom 1998, Brinkman et al. 2005). In addition, extreme variation in home range size can occur with age, sex, habitat, season (Demarais et al. 2000), and human activities (i.e., development, agricultural practices, hunting activities).

During this study, variation existed between seasonal home ranges. Mean 95% winter home ranges of deer in the Clark County area of eastern South Dakota ranged from 1.9 to 4.6 km^2 and mean 95% summer ranges ranged from 1.4 to 1.6 km^2, respectively. Previously documented mean 95% home range size of white-tailed deer (Brinkman 2003; 2.27-5.18 km^2; southwestern Minnesota, Swanson 2005; 2.57-3.31 km^2; southwestern Minnesota, Burris 2005; 1.04-4.57 km^2; western Minnesota and eastern South Dakota) varied slightly, relative to our study. However, Grovenburg et al. (2009) documented mean summer (3.6-15.6 km^2) and winter (3.9-9.1 km^2) home ranges of deer in east central South Dakota, that were greater than those found in the Clark County area. Smaller home ranges in our study, compared to those documented by Grovenburg et al. (2009) in east central South Dakota were likely due to the amount of suitable habitat/cover available. Although, tree cover was similar between the Clark County area (3.0%) and the east central South Dakota study area (2.3%, Grovenburg 2007), the Clark County area differed in the amount of semi-permanent wetlands covering the landscape. These wetland complexes consisted of large expanses of escape/thermal cover; deer utilized wetlands 24.9% of the time, potentially resulting in smaller summer and winter home ranges than those found in east central South Dakota. Likewise, Burris (2005) speculated white-tailed deer had smaller mean summer home ranges in Brookings County, South Dakota (1.55-1.68 km^2) because Brookings County deer utilized several wetland complexes and these complexes provided cover, water, forage, and other essential requirements. Kernohan et al. (1996) also documented that the basic needs of white-tailed deer in the Northern Great Plains can be found in a relatively small area. High densities of semi-permanent wetlands (> 20% of the landscape) in the Clark County study area likely contributed to smaller home range sizes because wetland complexes provided essential escape/thermal cover, water, and forage for white-tailed deer.

During winter 2009, mean 95% home ranges were significantly larger (4.6 km^2) than those from winter 2010 (1.92 km^2). We performed an analysis on 20 female radio-collared deer that survived the winters of 2009 and 2010. Home ranges were calculated from 16 February (date of capture in 2009) to median spring departure dates (6 April 2009 and 7 April 2010). In winter 2009, mean 95% home range during this time period was 4.26 km^2 (SE = 0.70 n = 20) and in winter 2010, mean 95% home range during the same time period was 2.09 km^2 (SE = 0.35 n = 20). During winter 2009, average snow depth and mean temperature from 16 February 2009 to 7 April 2009 were 8.02 cm and -5.4^{o} C. During 2010, average snow depth and mean temperature from 16 February 2009 to 7 April 2009 were 22.36 cm and -1.4^{o} C, respectively. Consequently, our analysis indicated that variation in winter home range size was explained best by average snow depth. Greater snow depth attributed to decreased mobility and forced deer to occupy a smaller area. Beier and McCullough (1990) noted that in northern regions, snow depth, and low temperatures had the greatest influence on daily activity of white-tailed deer. In response to severe weather conditions, deer will minimize movements to conserve energy (Moen 1976, Parker et al. 1984). White-tailed deer in the Clark County study area demonstrated these behavioral adaptations.

During our study, mean 95% summer home ranges were similar between 2009 (1.6 km^2) and 2010 (1.41 km^2). Throughout the summer months, white-tailed deer in this study area had high fidelity to core areas and spent the majority of their time in small, preferred, suitable patches of habitat. Bedding areas were consistently in the same locations and feeding areas varied with crop maturity and forage availability.

MANAGEMENT IMPLICATIONS

Our findings have immediate relevance for game managers and biologists in the Northern Great Plains regarding the influence of suitable habitat (i.e., wetlands and CRP grasslands) on white-tailed deer behavior. Wetlands provided essential cover for deer in the Clark County area, possibly resulting in shorter migration distances and smaller seasonal home ranges. Continued wetland loss through agricultural drainage practices may necessitate rapid adjustment in population management in particular units, such as Clark County. Increased loss of wetland and CRP grassland habitat may attribute to long migration distances and large seasonal home ranges. Limited patches of suitable habitat may lead to more deer crossing unit management boundaries. Loss of vital habitat must be taken into consideration during population modeling and in setting season recommendations in eastern South Dakota.

Additionally, the small home range sizes and short migration distances documented during this study indicate that deer populations, to a limited extent, may fluctuate spatially and temporally. Because these fluctuations are limited, population surveys conducted by South Dakota Game, Fish & Parks only need to be performed during winter or summer. However, seasonal movements do have the potential to fluctuate on an annual basis and continuous monitoring of variables impacting movement patterns is critical for successful management practices.

LITERATURE CITED

Barret, M. W., J. W. Nolan, and L. D. Roy. 1982. Evaluation of hand-held net-gun to capture large mammals. Wildlife Society Bulletin 10:108-114.

Beier, P., and D. R. McCullough. 1990. Factors influencing white-tailed deer activity patterns and habitat uses. Wildlife Monographs 109:1-51.

Beringer, J., L. P. Hansen, W. Wilding, J. Fischer, and S. L. Sheriff. 1996. Factors affecting capture myopathy in white-tailed deer. Journal of Wildlife Management 60:373-380.

Bowman, J. 2003. Is dispersal distance of birds proportional to territory size? Canadian Journal of Zoology 81:195-202.

Brinkman, T. J. 2003. Movement and mortality of white-tailed deer in southwest Minnesota. M.S. Thesis, South Dakota State University, Brookings, USA.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, J. D. Erb, and B. S. Haroldson. 2002. A vehicle-mounted radiotelemetry antenna system design. Wildlife Society Bulletin 30:258-262.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, B. S. Haroldson, and R. G. Osborn. 2005. Movement of female white-tailed deer: effects of climate and intensive row-crop agriculture. Journal of Wildlife Management 69:1099-1111.

Burris, B. M. 2005. Seasonal movements of white-tailed deer in eastern South Dakota and southwestern Minnesota relative to traditional ranges and management unit boundaries. M. S. Thesis, South Dakota State University, Brookings, USA.

Bryce, S., J.M. Omernik, D.E. Pater, M.Ulmer, J. Schaar, J.Freeouf, R.Johnson, P. Kuck, and S.H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/habitat/ndsdeco/index.htm>. Accessed 26 July 2011.

Carlsen, J. C., and R. E. Farmes. 1957. Movement of white-tailed deer tagged in Minnesota. Journal of Wildlife Management 21:397-401.

Clover, M. R. 1956. Single gate deer trap. California Fish and Game 42:199-201.

Cox, R. R., Jr., J. D. Scalf, B. E. Jamison, and R. S. Lutz. 2002. Using an electronic compass to determine telemetry azimuths. Wildlife Society Bulletin 30:1039-1043.

DelGuidice, G. D., B. A. Mangipane, B. A. Sampson, and C. O. Kochanny. 2001. Chemical immobilization, body temperature, and post-release mortality of white-tailed deer captured by Clover trap and net-gun. Wildlife Society Bulletin 29:1147-1157.

DelGuidice, G. D., B. A. Sampson, D. W. Kuehn, M. C. Powell and J. Fieberg. 2005. Understanding margins of safe capture, chemical immobilization, and handling of free-ranging white-tailed deer. Wildlife Society Bulletin 33:677-687.

Demarais, S., K. V. Miller, and H. A. Jacobson. 2000. White-tailed deer. Pages 601-628 *in* S. Demarais and P. R. Krausman, editors. Ecology and management of large mammals in North America. Prentice Hall, Inc., Upper Saddle River, New Jersey, USA.

Drolet C. A. 1976. Distribution and movements of white-tailed deer in southern New Brunswick in relation to environmental factors. Canadian Field Naturalist 90:123-136.

Gaudette, M. T., and D. F. Stauffer. 1988. Assessing habitat of white-tailed deer in southwestern Virginia. Wildlife Society Bulletin 16:284-290.

Griffin, S. L., J. F. Kennedy, L. A. Rice, and J. A. Jenks. 1994. Movements and habitat uses of white-tailed deer in the northern Black Hills South Dakota, 1990-1992. South Dakota Department of Game, Fish and Parks. Pittman-Robertson Game Report W-75-R-34 Pierre, USA.

Grovenburg, T. W. 2007. Movement patterns of white-tailed deer in east central South Dakota relative to winter ranges and management unit boundaries. M. S. Thesis, South Dakota State University, Brookings, USA.

Grovenburg, T. W., C. N. Jacques, C. C. Swanson, R. W. Klaver, and J. A. Jenks. 2010. Use of late season standing corn by female white-tailed deer in the northern Great Plains during a mild winter. The Prairie Naturalist 42(1/2):8-18.

Grovenburg, T. W., C. N. Jacques, R.W. Klaver, C. S. DePerno, T. J. Brinkman, C. C. Swanson, and J. A. Jenks. 2011. Influence of landscape characteristics on migration strategies of white-tailed deer. Journal of Mammalogy 92:534-543.

Grovenburg, T. W., J. A. Jenks, R. W. Klaver, C. C. Swanson, C. N. Jacques, and D. Todey. 2009. Seasonal movements and home ranges of white-tailed deer in north-central South Dakota. Canadian Journal of Zoology 87:876-885.

Hoskinson, R. L., and L. D. Mech. 1976. White-tailed deer migration and its role in wolf predation. Journal of Wildlife Management 40:429-441.

Kernohan, B. J. 1994. Winter/spring population characteristics of white-tailed deer in an agricultural/wetland complex in northeastern South Dakota. M. S. Thesis, South Dakota State University, Brookings, USA.

Kernohan, B. J., J. A. Jenks, and D. E. Naugle. 1994. Movement patterns of white-tailed deer at Sand Lake National Wildlife Refuge, South Dakota. The Prairie Naturalist 26:293-300.

Kernohan, B. J., J. A. Jenks, D. E. Naugle, and J. J. Millspaugh. 1996. Estimating 24-h habitat use patterns of white-tailed deer from diurnal use. Journal of Environmental Management 48:299-303.

Kernohan, B. J., J. A. Jenks, and D. E. Naugle. 2002. Localized movements and site fidelity of white-tailed deer in the northern great plains. The Prairie Naturalist 34(1/2):1-12.

Kernohan, B. J., J. J. Millspaugh, J. A. Jenks, and D. E. Naugle. 1998. Use of an adaptive kernel home-range estimator in a GIS environment to calculate habitat use. Journal of Environmental Management 53:83-89.

Jacques, C. N., J. A. Jenks, C. S. DePerno, J. D. Sievers, T. W. Grovenburg, T. J. Brinkman, C. C. Swanson, and B. A. Stillings. 2009. Evaluating ungulate mortality associated with helicopter net-gun captures in the northern Great Plains. Journal of Wildlife Management 73:1282-1291.

Johnson, D. H. 1994. Population analysis. Pages 419-444 *in* T. Bookout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Johnson, R. R., K. F. Higgins, M. L. Kjellsen, and C. R. Elliott. 1997. Eastern South Dakota wetlands. Brookings: South Dakota State University. Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/wetlands/eastwet/index.htm>. Accessed 9 July 2011.

Johnson, J. R., and G. E. Larson. 1999. Grassland plants of South Dakota and the Northern Great Plains. South Dakota State University College of Agriculture & Biological Sciences, South Dakota Agriculture Experiment Station, Brookings, USA.

Lewis, T. L., and O. J. Rongstad. 1998. Effects of supplemental feeding on white-tailed deer, *Odocoileus virginianus*, migration and survival in northern Wisconsin. Canadian Field Naturalist 112:75-81.

Long, E. S., D. R. Diefenbach, C. S. Rosenberry, B. D. Wallingford, and M. D. Grund. 2005. Forest cover influences dispersal distance of white-tailed deer. Journal of Wildlife Mammalogy 86:623-629.

Marchington. R. L., and D. H. Hirth. 1984. Behavior. Pages 129-168 *in* L. K. Halls, editor. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Pennsylvannia, USA.

Moen, A. N. 1976. Energy conservation by white-tailed deer in the winter. Ecology 57:192-198.

Morgan, J. T.,and G. L. Dusek. 1992. Trapping white-tailed deer on summer range. Wildlife Society Bulletin 20:39-41.

Nams, V. O. 2006. Locate III User's Guide. Pacer Computer Software, Tatamagouche, Nova Scotia, Canada.

National Climatic Data Center. 2011. Record of Climatological Observations. <http://www7.ncdc.noaa.gov/IPS/coop/coop.html>. Accessed 9 May 2011.

Naugle, D. E., B. J. Kernohan, and J. A. Jenks. 1995. Seasonal capture success and bait use of white-tailed deer in an agricultural-wetland complex. Wildlife Society Bulletin 23:198-200.

Naugle, D. E., J. A. Jenks, B. J. Kernohan, and R. R. Johnson. 1997. Effects of hunting and loss of escape cover on movements and activity of female white-tailed deer, *Odocoileus virginianus*. Canadian Field Naturalist 111:595-600.

Nelson, M. E. 1998. Development of migratory behavior in northern white-tailed deer. Canadian Journal of Zoology 76:426-432.

Nelson, M. E. 1995. Winter range arrival and departure of white-tailed deer in northeastern Minnesota. Canadian Journal of Zoology 73:1069-1076.

Nelson, M. E., and L. D. Mech. 1981. Deer social organization and wolf predation in northeastern Minnesota. Wildlife Monographs 77:1-53.

Nixon, C. M., L. P. Hansen, P. A. Brewer, and J. E. Chelsvig. 1991. Ecology of white-tailed deer in an intensively farmed region of Illinois. Wildlife Monographs 118:1-77.

Ozoga, J. J., and L. W. Gysel. 1972. Response of white-tailed deer to winter weather. Journal of Wildlife Management 36:892-896.

Ozoga, J. J., L. S. Verme, and C. S. Bienz. 1982. Parturition behavior and territoriality in white-tailed deer: impact on neonatal mortality. Journal of Wildlife Management 46:1-11.

Parker, K. L., C. T. Robbins, and T. A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management 48:474-488.

Porter, W. F., H. B. Underwood, and J. L. Woodard. 2004. Movement behavior, dispersal, and the potential for localized movement of deer in a suburban environment. Journal of Wildlife Management 68:247-256.

Rodgers, A. R., and A. P. Carr. 1998. HRE: The home range extension for ArcView. Center for Northern Forest Ecosystem Research, Ontario Ministry of Natural Resources, Ontario, Canada.

Rongstad, O. J., and J. R. Tester. 1969. Movements and habitat use of white-tailed deer in Minnesota. Journal of Wildlife Management 33:366-379.

Root, B. G., E. K. Fritzell, and N. F. Giessman. 1988. Effects of intensive hunting on white-tailed deer movement. Wildlife Society Bulletin 16:145-151.

Rosenberry, C. S., R. A. Lancia, and M. C. Conner. 1999. Population effects of white-tailed deer dispersal. Wildlife Society Bulletin 27:858-864.

Sabine, D. L., S. F. Morrison, H. A. Whitlaw, W. B. Ballard, G. J. Forbes, and J. Bowman. 2002. Migration behavior of white-tailed deer under varying winter climate regimes in New Brunswick. Journal of Wildlife Management 66:718-728.

Schwede, G., H. Hendrichs, and W. McShea. 1993. Social and spatial organization of female white-tailed deer, *Odocoileus virginianus*, during the fawning season. Animal Behavior 45:1007-1017.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739-747.

Severinghaus, C. A. 1949. Tooth development and wear as criteria of age in white-tailed deer. Journal of Wildlife Management 13:195-216.

Severinghaus, C. A. and E. L. Cheatum. 1956. Life and times of the white-tailed deer. Pages 57-186 *in* W. P. Taylor, editor. The Deer of North America. Stackpole Books. Harrisburg, Pennsylvania, USA.

Simon, D. E. 1986. Density, migration, and mortality patterns of white-tailed deer using a sanctuary in southeastern Minnesota. M.S. Thesis, University of Minnesota, St. Paul, Minnesota, USA.

Smith, V. J., J. A. Jenks, C. R. Berry, Jr., C. J. Kopplin, and D. M. Fecske. 2002. The South Dakota Gap Analysis Project. Final Report. Research Work Order No. 65. Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, S.D, USA.

South Dakota Agriculture Statistics Service. 2010. Census of agriculture. South Dakota Department of Agriculture, Pierre, USA. <http://www.nass.usda.gov/sd/>. Accessed 6 June 2011.

South Dakota Department of Game, Fish and Parks. 2010*a*. 2009 Big game harvest projections. South Dakota Game Report No 2011-05. Division of Wildlife, South Dakota Department of Game, Fish and Parks, Pierre, USA.

South Dakota Department of Game, Fish and Parks. 2010*b*. South Dakota 2010 Hunting Atlas. Midstates Printing Inc. Pierre, USA.

South Dakota Office of Climatology. 2011. South Dakota climate and weather. <http://climate.sdstate.edu>. Accessed 2 May 2011.

Sparrowe, R. D., and P. F. Springer. 1970. Seasonal activity patterns of white-tailed deer in eastern South Dakota. Journal of Wildlife Management 34:420-431.

Swanson, C. C. 2005. Movement and association of white-tailed deer in southwest Minnesota. M. S. Thesis, South Dakota State University, Brookings, USA.

United States Department of Agriculture. 2009. National Agricultural Imagery Program (NAIP). Farm Service Agency. <http://www.fsa.usda.gov/FSA/. apfoapp?area=home&subject=prog&topic=nai>. Accessed 8 February 2009.

U.S. Geological Survey, Gap Analysis Program (GAP). 2010. National Land Cover, version 1. <http://gapanalysis.usgs.gov/data/land.cover.data>. Accessed 23 May 2011.

Van Deelen, T. R., H. Campa III, M. Hamady, and J. B. Haufler. 1998. Migration and seasonal range dynamics of deer using adjacent deeryards in northern Michigan. Journal of Wildlife Management 62:205-213.

VerCauteren, K. C., and S. E. Hygnstrom. 1998. Effects of agricultural activities and hunting on home ranges of female white-tailed deer. Journal of Wildlife Management 62:280-285.

Verme, L. J. 1973. Movement of white-tailed deer in upper Michigan. Journal of Wildlife Management 37:545-552.

Zar, J. H. 1999. Biostatistical Analysis. Prentice Hall, Inc., Upper Saddle River, New Jersey, USA.

Table 2-1. Mean seasonal migration distance (km) by capture site for radio-collared white-tailed in Clark County, South Dakota, 2009-2011.

	2009 Spring Migration (*n*, SE)	2009 Fall Migration (*n*, SE)	2010 Spring Migration (*n*, SE)	2010 Fall Migration (*n*, SE)
Clark County	4.82 (12, 1.02)	5.37 (11, 0.73)	5.02 (20, 0.61)	3.77 (13, 0.74)

Table 2-2. Mean 50 and 95% home range size (km^2) for radio-collared white-tailed deer in eastern South Dakota, 2009-2010. Home ranges calculated using LSCV method.

Season	50%	95%
2009 Winter (*n*, SE)	1.07 (22, 0.21)	4.6 (22, 0.81)
2009 Summer (*n*, SE)	0.32 (25, 0.03)	1.6 (25, 0.16)
2010 Winter (*n*, SE)	0.44 (36, 0.06)	1.92 (36, 0.24)
2010 Summer (*n*, SE)	0.31 (36, 0.03)	1.41 (36, 0.12)

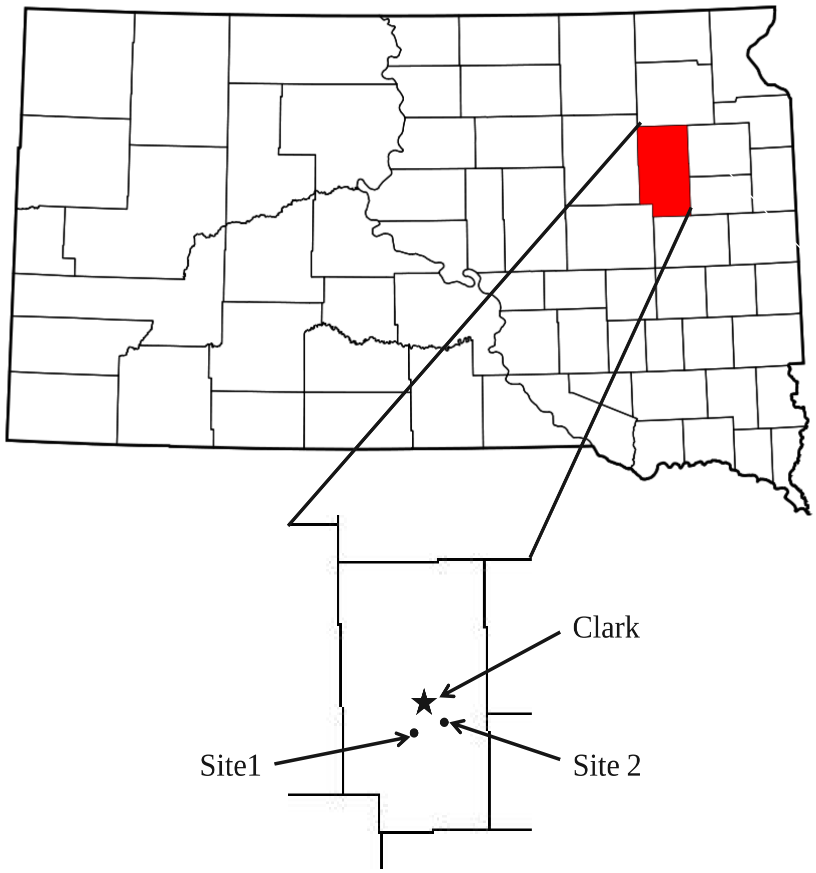
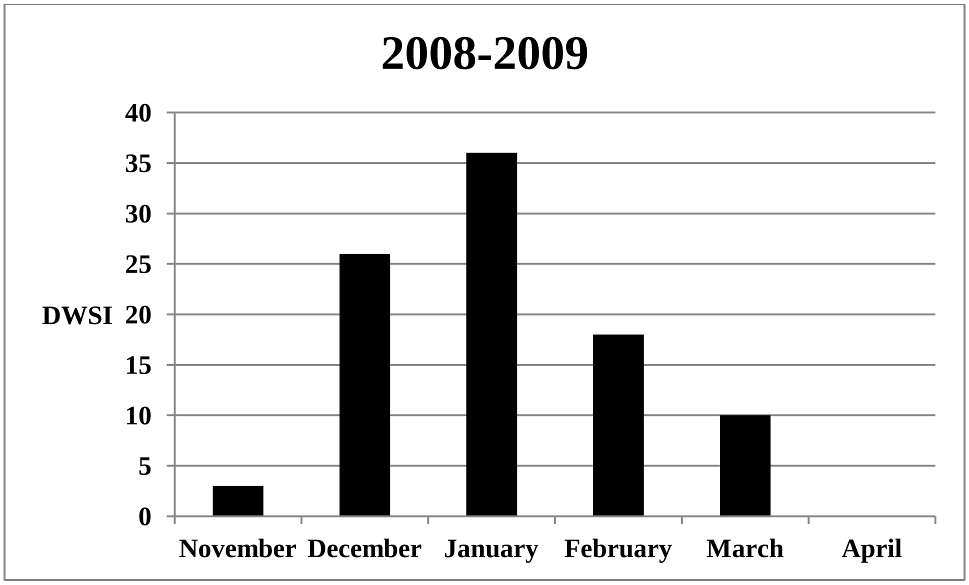


Figure 2-1. Clark County study area for white-tailed deer in eastern South Dakota, 2009-2011 with designated helicopter capture sites.



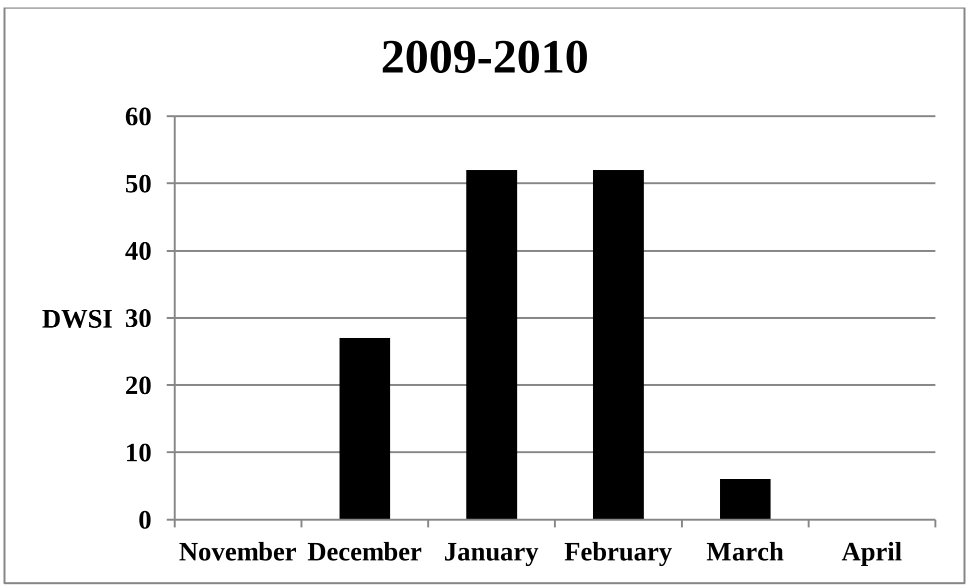
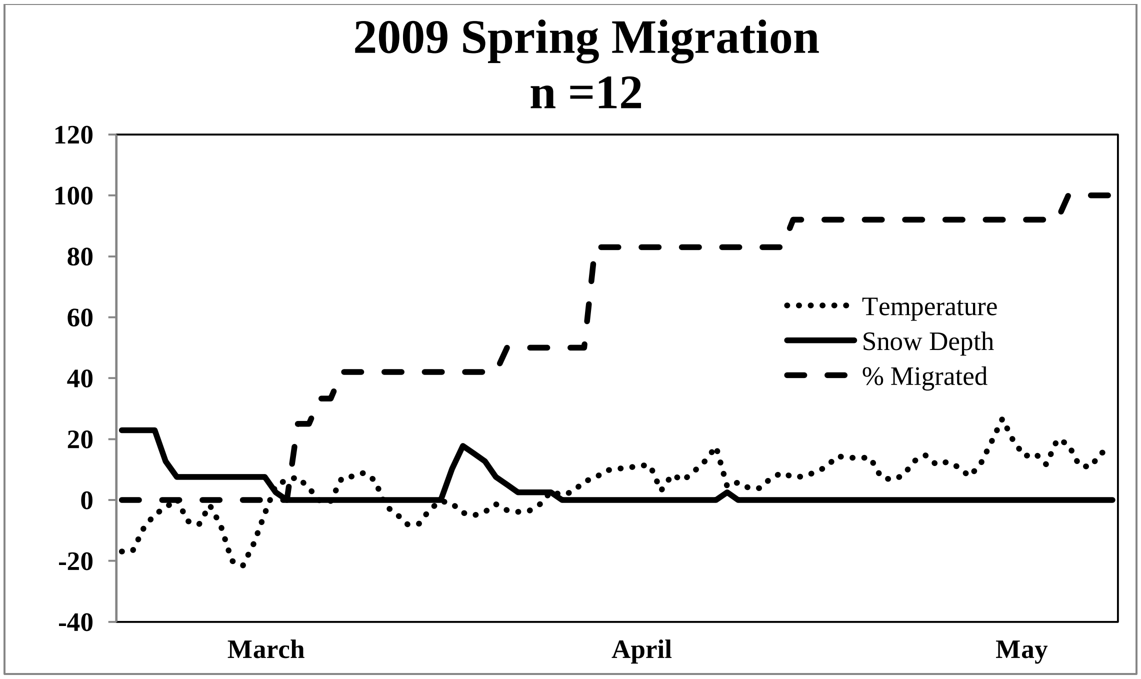


Figure 2-2. Monthly deer winter severity indices (DWSI) for Clark County, South Dakota. We assigned one point for each day mean temperature was ≤ -7 °C and an additional point for each day snow depth was ≥ 35.0 cm; National Climatic Center of Climatology 2011.



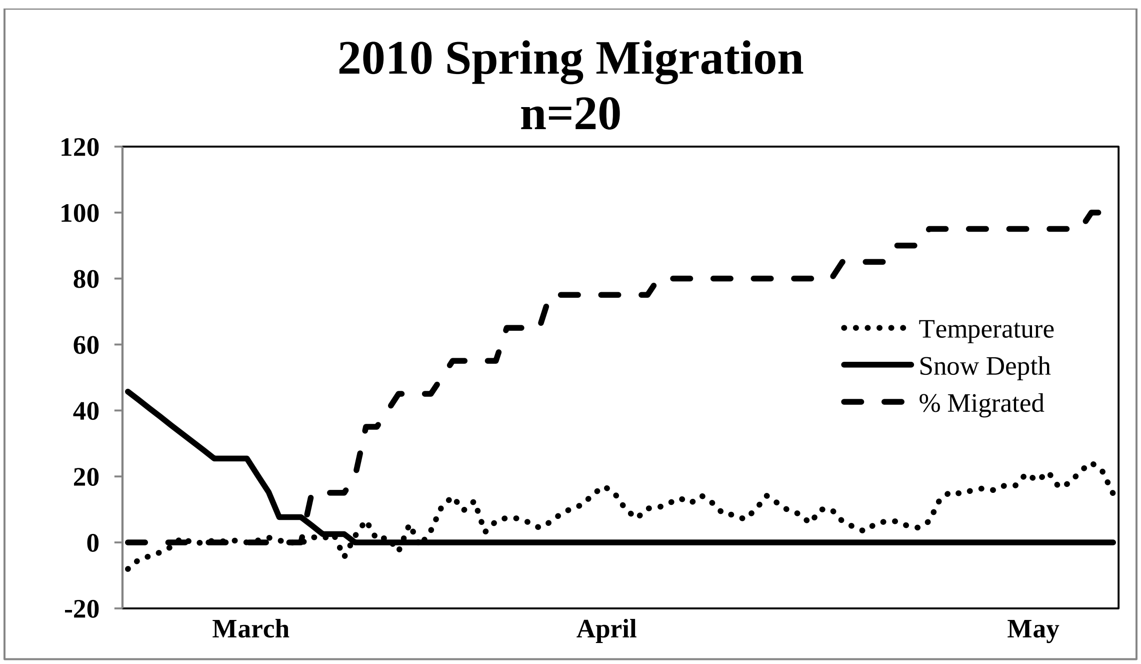
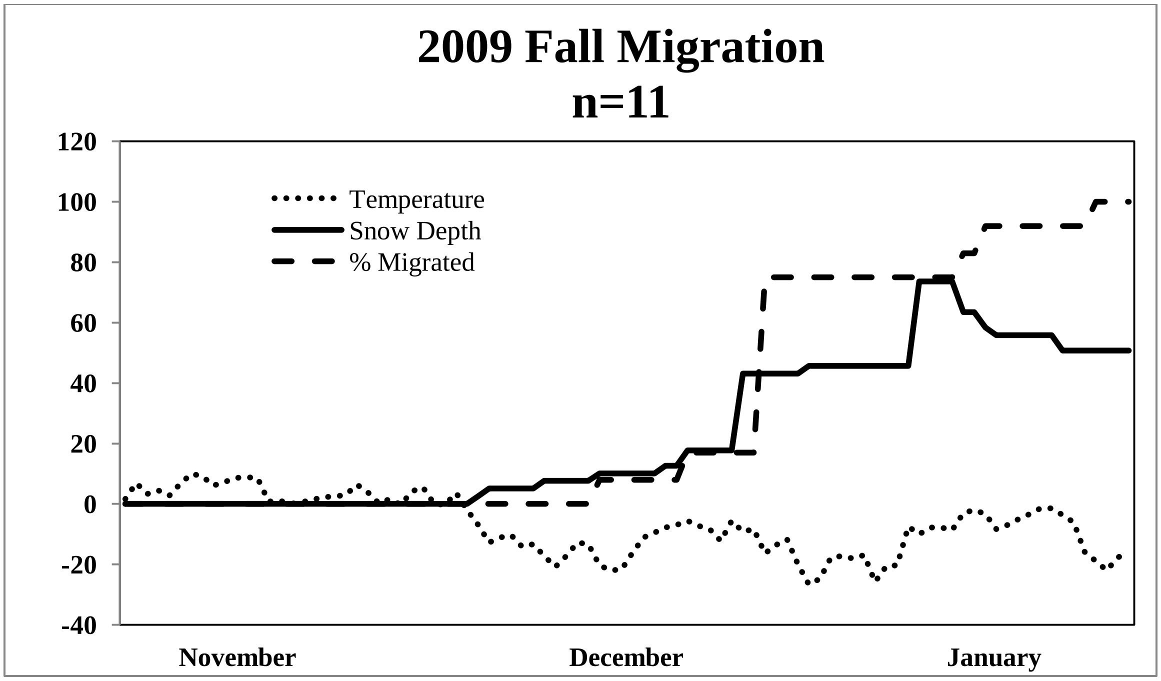


Figure 2-3. Spring migration for radio-collared white-tailed deer in Clark County, South Dakota. Three variables compose the Y-axis (i.e. temperature [^{o}C], snow depth [cm], migratory deer [%]).



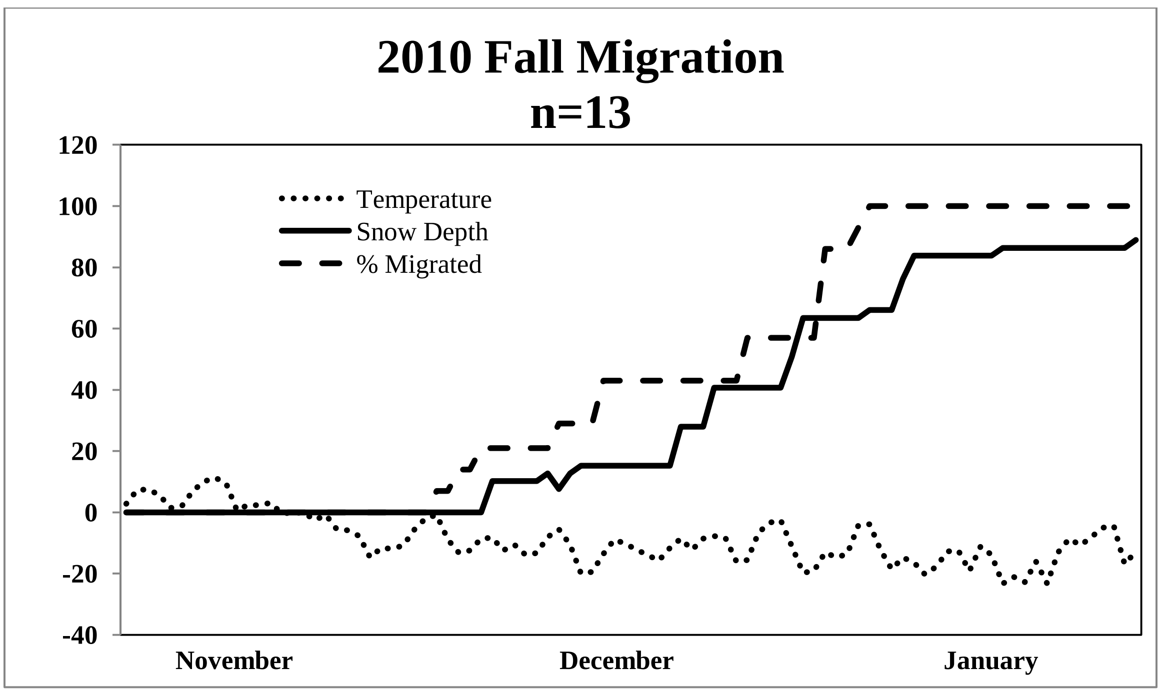


Figure 2-4. Fall migration for radio-collared white-tailed deer in Clark County, South Dakota. Three variables compose the Y-axis (i.e. temperature [^{o}C], snow depth [cm], migratory deer [%])

CHAPTER 3: SURVIVAL OF WHITE-TAILED DEER IN EASTERN SOUTH DAKOTA

ABSTRACT Throughout the Northern Great Plains, cause-specific mortality and survival of white-tailed deer have been well documented; however, limited information exists regarding cause-specific mortality and survival in the Prairie Pothole Region of eastern South Dakota where semi-permanent wetland densities are relatively high. The objectives of this study were to document cause-specific mortality and survival of white-tailed deer. From February 2009 – February 2011, 30 adult (>1.5 years) and 13 yearling (8-18 months) female white-tailed deer were monitored for survival using radio telemetry in Clark County, South Dakota. During this study, 17 deer died, and overall (24 month) survival was 0.55 (SE=0.08, *n*=43). Annual survival rates during 2009 and 2010 were 0.78 (SE = 0.08, *n* = 26) and 0.70 (SE = 0.08, *n*= 37), respectively. Seasonal survival rates for post-hunt, pre-hunt, and hunting seasons during 2009 and 2010 were 0.96 (SE= 0.04, *n*=26), 1.00 (SE < 0.001, *n*= 25), 0.84 (SE = 0.07, *n*= 34) and 0.94 (SE = 0.04, *n*= 37), 1.00 (SE < 0.001, *n*= 36), and 0.72 (SE = 0.07, *n*= 36), respectively. Survival was dependent on hunting, which was responsible for 64.7% of all mortalities. Liberal antlerless tag numbers, lengthy hunting seasons, and high hunter densities likely influenced human related mortality of white-tailed deer in this region.

INTRODUCTION

Understanding survival and cause-specific mortality is essential when managing white-tailed deer populations (DePerno et al. 2000, DelGuidice et al. 2002, Brinkman et al. 2004). These data provide critical information for constructing population and harvest models (Ballard et al. 1999). Numerous radiotelemetry studies of white-tailed deer in the Northern Great Plains have demonstrated that survival and cause-specific mortality rates fluctuate regionally and seasonally (Grassel 2000, Brinkman et al. 2004, Burris 2005, Grovenburg et al. 2011). Common causes of mortality in northern regions include natural and human-related factors (DelGiudice et al. 2002, Burris 2005, Grovenburg et al. 2011), such as hunting, vehicle collisions, poaching (Fuller 1990, Dusek et al. 1992, Brinkman et al. 2004, Porter et al. 2004, Grovenburg et al. 2011), severe weather conditions (DelGiudice et al. 2002), predation (Mech 1984, VanDeelen et al. 1997, Whitlaw et al. 1998) starvation (Lamoureux et al. 2001), and disease (Matschke et al. 1984). Most studies have shown that hunter harvest is the primary cause of mortality and quantifying harvest mortality rate is critical for proper management of deer (DelGiudice et al. 2002).

Reliable survival estimates along with cause-specific mortality are needed by South Dakota Game, Fish and Parks (SDGFP) for modeling purposes. Without such data, overexploitation or underexploitation of hunted populations is possible (Nelson and Mech 1986). Models are used by SDGFP to calculate population estimates and determine how many deer can be harvested to keep populations at acceptable levels. These models are heavily relied upon to allocate tag numbers and make season recommendations. Other variables included in models are sex ratios, harvest data, and reproductive rates (South Dakota Department of Game, Fish and Parks 2011).

Although, survival and cause-specific mortality have been well documented in the Northern Great Plains region (Grassel 2000, Brinkman et al. 2004, Swanson 2005, Burris

2005, Grovenburg 2007), limited information exists in the Clark County area, where wetlands cover > 20% of the landscape. Also, antlerless deer tags have been reduced in Clark County since 2007, possibly affecting survival rates (South Dakota Department of Game, Fish and Parks 2011). The primary objective of this study was to document overall, annual, and seasonal survival rates and the secondary objective was to determine cause-specific mortality for white-tailed deer in this region.

STUDY AREA

Our study was conducted from January 2009 to February 2011 in Clark County, South Dakota (Figure 1), which comprised an area of 1,294 km^2. Mean annual (30-yr) precipitation was 56.2 cm and mean (30-yr) monthly temperature ranged from -11.9^{o} C to 21.8^{o} C (South Dakota Office of Climatology 2011). Clark County is located in the level III ecoregion of the Northern Glaciated Plains (Bryce et al. 1998) and lies in the Prairie Pothole Region (Johnson et al. 1997). Soils of the area are composed of glacial till and the county is typified by flat to gently rolling terrain intermixed with numerous semi-permanent, temporary, and seasonal wetlands that were formed by glaciers (Bryce et al. 1998, Johnson et al. 1997). The glacial till soil is fertile and the predominant land use in Clark County is agriculture with cultivated land and pasture/hay land comprising 45.2% and 19.0% of total land use, respectively. Wetlands comprise 11.6% and grassland systems make up another 11.0 % of the county (U.S. Geological Survey 2010). However, the 1,294 km^2 study area within Clark County was unique in that cultivated crops, including corn (*Zea mays*), soybeans (*Glycine max*), and wheat (*Triticum aestivum*) comprised 48% and pasture land comprised 8% of the landscape. In contrast, wetlands and grasslands comprised 23% and 15% of the landscape. Trees (i.e., woodland plantings and shelterbelts) and developed areas (i.e., roads, buildings, and cattle feedlots) each covered 3% of the area (Smith et al. 2002).

Native warm and cool season grasses were planted on lands that were enrolled in the Conservation Reserve Program (CRP). These grasses included, but were not limited to, big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), western wheatgrass (*Elymus smithii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and smooth brome (*Bromus inermis*). Wetland vegetation was dominated by cattails (*Typha* spp.), sedges (*Carex* spp.), rushes (*Juncus* spp.), reed canary grass (*Phalaris arundinacea*), prairie cordgrass (*Spartina pectinata*), and common reed (*Phragmites australis*). In this area, woodlands and shelterbelts were comprised of American elm (*Ulmus americana*), green ash (*Fraxinus pennslyvanica*), eastern cottonwood (*Populus deltoides*), boxelder (*Acer negundo*) and eastern red ceder (*Juniperus virginiana*: Johnson and Larson 1999). Clark County is dominated by private land; however, a mixture of State Game Production Areas, Federal Waterfowl Production Areas and, Walk-In Areas (Private land hunting access) existed, allowing limited public hunting opportunities (South Dakota Hunting Atlas 2010).

In Clark County, hunting seasons for white-tailed deer were open from 11 September – 31 January 2009-10. These seasons included youth antlerless firearm, occurring from 11 September – 31 January; archery, occurring from 25 September – 31 January; East River firearm, occurring from 20 November – 6 December, additional antlerless seasons occurring 26 December – 3 January 2010 and 1 January – 9 January

2011, and muzzleloader seasons occurring from 11 December – 31 January (South Dakota Department of Game, Fish and Parks 2009, 2010).

METHODS

From 22 January to 15 February 2009 and from 7 January to 25 February 2010 we captured white-tailed deer using modified Clover traps (Clover 1956) and helicopter net guns (DelGuidice et al. 2001, Jacques et al. 2009) in the southern half of Clark County (Figure 1). We directed trapping and net gunning efforts towards adult females because they are most important in assessing reproduction and normally dominate white-tailed deer harvest in eastern South Dakota (South Dakota Department of Game, Fish and Parks 2010). We baited trapping sites with a combination of high quality alfalfa (*Medicago sativa),* shelled corn, and molasses. Concerns regarding animal welfare were addressed by checking traps daily at first light and captured individuals were manually restrained and blindfolded to reduce stress.

Deer captured with the helicopter net-gun were restrained, hobbled, and blindfolded by a crewmember that exited the helicopter after net-gunning occurred. Deer were then transported below the helicopter, in canvas transport bags, to the processing site where crew members quickly removed them from the transport bags and continuously monitored rectal temperature as an index to stress (DelGuidice et al. 2001). If body temperatures exceeded 40 ^{o}C, we applied a mixture of ice water and isopropyl alcohol ventrally to the deer to reduce body temperature and stabilize the animal (Grovenburg 2007). We recorded processing time and distance from the capture location for each individual.

All captured deer were sexed and aged as fawn (~8-10 months), yearling (8 – 18 months) or adult (> 1.5 years) based on tooth replacement and incisor wear (Severinghaus 1949, Severinghaus and Cheatum 1956). We ear-tagged all animals with metal and plastic ear-tags (Hasco Tag Company, Dayton, KY, USA) and we fitted adult females with VHF (Very High Frequency) radiocollars (Advanced Telemetry Systems, Inc., Isanti, MN) that were equipped with mortality sensors, which activated if the collar remained still for 8 hours. Animals captured with the helicopter net gun were administered an intramuscular injection of a broad-spectrum antibiotic, penicillin. We examined overall physical condition of captured animals and removed blindfolds and hobbles before the animals were released. All methods described in this research were approved by the Institutional Animal Care and Use Committee (IACUC, Approval No. 08-A028) at South Dakota State University.

All radiocollared deer were monitored 2-3 times weekly for survival using a vehicle mounted "null-peak" antenna system (Brinkman et al. 2002). We never located animals on successive days and we tracked them at different times of the day, including nights, to maintain temporal independence and to ensure accurate home range estimates (Kernohan et al. 1998). We excluded mortalities ≤26 days post capture from analyses (Beringer et al. 1996). We located all mortalities using a hand-held Yagi antenna attached to a receiver (Advanced Telemetry Systems, Inc., Isanti, MN, USA). Field necropsies were performed on all mortalities and carcass-site evidence was examined to determine cause of death. If we could not determine cause of death in the field, the carcass was transported to the Animal Disease Research Diagnostic Laboratory at South Dakota State University for further examination.

We calculated overall, annual, and seasonal survival rates using the Kaplan-Meier method (Kaplan and Meier 1958) adapted for staggered entry (Pollack et al. 1989) in Program MARK version 6.0 (White and Burnham 1999, Cooch and White 2006). Seasonal survival rates were separated into three time intervals; pre-hunt (1 May – 31 August), hunt (1 September – 31 December), and post-hunt (1 January – 30 April) (Brinkman et al. 2004, Burris 2005, Grovenburg et al. 2011).

We calculated deer winter severity indices (DWSI; Brinkman et al. 2005) for the Clark County area during the winters of 2008-09 and 2009-10. We assigned one point for each day mean temperature was ≤ -7 ^{o}C and an additional point for each day snow depth was ≥ 35.0 cm (Brinkman et al. 2005) during the months of October-April using information collected by the National Climatic Data Center (2011).

RESULTS

We captured and radiocollared 30 adult (>1.5 years) and 13 yearling (8-18 months) female deer during January-February 2009 (n=26; Appendix A) and January-February 2010 (n=17; Appendix B) in the southern portion of Clark County, South Dakota, via helicopter nets and Clover traps (Figure 1). In addition, we captured and ear-tagged 20 deer (1 adult male, 1 yearling male, 9 male fawns, 9 female fawns; Appendix A, B) via Clover traps. Two capture related mortalities occurred during helicopter net-gunning and Clover trapping operations in 2009 and 2010. A yearling female white-tailed deer was injured (fractured right pelvis) when netted from the helicopter and was euthanized at the processing site. A female fawn was found dead in a Clover trap; the carcass was transported to the Animal Disease Research and Diagnostic Laboratory at South Dakota State University (SDSU) and gross examination revealed a severe anteroventral abscessing pneumonia affecting the majority of lung lobes. Average DWSI for the winter 2008-2009 and 2009-2010 (Figure 2) was 93.0 and 137.0, respectively, for Clark County.

During the 24-month study (February 2009 – February 2011), 17 deer died and all mortalities were included in survival analyses (Appendix E). Eleven (64.7%) mortalities were due to human-related factors; all caused by rifle hunting (Figure 3). Additionally, 2 (11.8%) deer were killed by Canid predation, 2 (11.8%) by disease, and 2 (11.8%) were attributed to unknown causes.

On 22 April 2010, a radiocollared yearling female was found dead and transported to the Animal Disease Research and Diagnostic Laboratory at South Dakota State University (SDSU) where she was diagnosed with a prolapsed uterus and associated peritonitis. Gross examination revealed the body was emaciated with moderate autolysis present. The mucosal surface of the prolapsed uterus was extremely necrotic, dry, and friable. We speculate this animal had parturition issues and later succumbed to infection. Thus, cause of death was classified as disease.

The two individuals in which cause of death could not be determined included a yearling female that died on or before 28 December 2009. This individual was discovered two days after a severe winter snow storm that deposited 26 cm of snow. The carcass of the animal was completely consumed and only the skeletal structure remained.

This animal was located via triangulation on 23 December and the radiocollar signal was not in mortality mode; however, the location was within 50 m of where the carcass was located. We speculate the animal was already deceased during location efforts and Canids kept the radiocollar on live mode by moving the carcass while consuming the remains. This individual died while demonstrating migratory behavior and was en route to her winter range.

On 15 February 2011, a mortality signal was received from deer number 150374 (adult female). This individual was found covered by 10 cm of snow that fell on 13 February and was completely consumed, except for skeletal remains. The carcass was lying in a picked corn field and was > 300 m from suitable cover. Cause of death could not be classified as predation because only partial remains were present and recent snow fall had covered the site.

Annual survival rates during 2009 and 2010 were 0.78 (SE=0.08, *n*=26; Table 1) and 0.70 (SE=0.08, *n*=37; Table 1), respectively. Overall (24 month) survival rate for the entire study (February 2009 – February 2011) was 0.55 (SE=0.08, *n*=43; Table 1). Seasonal survival rates for post-hunt, pre-hunt, and hunting seasons during 2009 and 2010 were 0.96 (SE= 0.04, *n*=26), 1.00 (SE < 0.001, *n*= 25), 0.84 (SE = 0.07, *n*= 34; Table 2), and 0.94 (SE = 0.04, *n*= 37), 1.00 (SE < 0.001, *n*= 36), 0.72 (SE = 0.07, *n*= 36; Table 2), respectively. All mortalities occurred during the hunt and post-hunt seasons (*n*=17; Table 3). Furthermore, 3 (15.0%) ear-tagged male deer were recovered during this study (Appendix F). One (33.3%) mortality was attributed to archery harvest, 1 (33.3%) to a vehicle collision, and 1 (33.3%) to unknown causes.

DISCUSSION

Our findings for annual survival rates for female white-tailed deer in eastern South Dakota during 2009 (78%; Table 1) and 2010 (70%; Table 1) were similar to previously documented rates in northeastern Minnesota (79%; Nelson and Mech 1986), northern New York (75-88%; Jones et al. 1997), northern Michigan (77%; Van Deelen et al. 1997), New Brunswick (66-85%; Whitlaw et al. 1998), central Black Hills of South Dakota (50-62%; DePerno et al. 2000), Illinois (56-92%; Nixon et al. 2001), southwestern Minnesota (77%; Brinkman et al. 2004), eastern South Dakota and western Minnesota (69-86%; Burris 2005), east central South Dakota (65-84%; Grovenburg 2007), and throughout the Northern Great Plains (76%; Grovenburg et al. 2011). Limited variation exists in the survival rates of female white-tailed deer throughout the Midwest. We speculate annual survival in the Clark County area closely resembled previous research findings because, similar to other deer populations in the Midwest, survival in the Clark County study area was predominantly dependent on hunting, with rifle hunting accounting for 64.7% of all mortalities (Figure 3). These results were similar to those documented in eastern Montana (74%; Dusek et al. 1992), northern Wisconsin (63%; Lewis and Rongstad 1998), eastern South Dakota and southwestern Minnesota (68%; Burris 2005), east central South Dakota (61.1%; Grovenburg 2007), and throughout the Northern Great Plains (69.9%; Grovenburg et al. 2011). However, in areas where doe harvest is limited, as it was in southern New Brunswick, hunting mortality accounted for 13% of all mortalities (Whitlaw et al. 1998). In addition, lower hunting mortality rates also were documented in north-central Minnesota (43%; DelGiudice et al. 2002), where wolf predation along with severe winter weather greatly impacted white-tailed deer survival. In southwestern Minnesota, hunting mortality rates of 43% were reported where vehicle collisions accounted for 23% of all deer mortalities (Brinkman et al. 2004).

During 2009-2011, seasonal survival rates for post-hunt (0.94 and 0.96), pre-hunt (1.00 and 1.00), and hunting (0.84 and 0.72; Table 2) periods were similar to those documented by Brinkman et al. (2004: 0.96, 1.00, and 0.8) in southwestern Minnesota and Burris (2005: 0.97, 0.95, and 0.84) in eastern South Dakota and western Minnesota, and Grovenburg (2007: 0.985, 0.985 and 0.72) in east central South Dakota. Survival was highest during the pre-hunt period, indicating minimal human interactions, high availability of quality forage, and suitable escape cover (Nixon et al. 1991, Brinkman et al. 2004). Seasonal survival was lowest during the hunting period due to the effects of hunter harvest.

In eastern South Dakota, white-tailed deer may have experienced high hunting mortality rates because of interspersed escape cover, well established road networks, and a long 16-day rifle harvest season. Patches of tree cover and wetland complexes were often >1.0 km apart in home ranges, resulting in high vulnerability of deer while moving across open terrain to occupy adjacent cover habitats. Established roads were present throughout the study area and in most areas they existed every 1.6 km. Firearm hunting success rates in Clark County were low in 2009 (34%) and 2010 (46%; South Dakota Department of Game, Fish and Parks 2009, 2010). Success rates may have been low in 2009 because of unharvested crops that remained in agricultural fields, resulting from an unseasonably cool, wet fall (National Climatic Data Center 2009). We speculate that if hunter harvest rates were higher in 2009 and 2010, decreased survival for white-tailed deer in the Clark County would have possibly occurred (Dusek et al. 1992).

Natural causes of mortality such as predation and disease accounted for 24.5% of deer mortality in the Clark County area. These results differ from those reported in southwest Minnesota (14.2%; Brinkman et al 2004), eastern South Dakota and southwest Minnesota (8%; Burris 2005), and east central South Dakota (0%; Grovenburg et al. 2011). Higher natural mortality rates may have been attributed to severe winter weather that occurred during this study. In the Clark County area, average DWSIs during 2008-2009 (93.0), 2009-2010 (137.0) and 2010-2011 (168.0) were severe; compared to previous research conducted in eastern South Dakota by Burris (2005) and Grovenburg et al. (2009) that reported DWSIs between 36.0 - 68.7, respectively. In northern regions, winter severity has impacted survival of white-tailed deer (Fuller 1990, DelGiudice et al. 2002). Severe winters can potentially lead to starvation (White et al. 1987, Lamoureux et al. 2001) as well as the inability to maintain body core temperatures, weakening the immune system and increasing the susceptibility of bacterial infections (Hanley et al. 1989, DePerno et al. 2003). McDonald et al. (1973) documented that white-tailed deer generate additional body heat when temperatures are $\leq -7^{o}$ C. Furthermore, animals expend a greater amount of energy moving through deep snow (Robbins 2001). Therefore, winter severity likely influenced natural causes of mortality that occurred in the Clark County area.

We documented no vehicle collisions for radiocollared deer during the duration of this study. These results differed from those reported by Grovenburg et al. (2011) who reported that of 113 mortalities documented in southern Minnesota and eastern South Dakota, 15% were caused by vehicle collisions. We speculate that even though established road networks were present in the Clark County area, white-tailed deer demonstrated limited movement patterns, resulting in small seasonal home ranges and short migration distances. As a result, deer traveled over roads less often, which most likely limited vehicle collisions.

MANAGEMENT IMPLICATIONS

Survival estimates are important for population modeling purposes and to estimate population size and potential harvest quotas. South Dakota Game, Fish and Parks biologists have detailed harvest estimates based on hunter surveys. By understanding harvest mortality, biologists can model population size by extrapolating the total number of deer that died from all forms of mortality to estimate population size. Mortality rates and causes of mortality have been consistent over the last ten years throughout the Northern Great Plains.

Because the proximate cause of mortality found in this region is hunting, managers need to adjust permits to meet population objectives. Hunter harvest has definite effects on the population and drastic changes in tag numbers can result in overexploitation or overabundance, depending on the situation. Loss of suitable escape cover (wetlands, CRP grasslands, and shelterbelts) will likely lower white-tailed deer survival in this region because deer would become more susceptible to harvest. Likewise, severe winter weather has a limited effect on survival and this study provided evidence that identified the relationship between severe winter weather and mortality.

However, managers must be aware that survival rates do fluctuate on an annual basis and these fluctuations are likely caused by changes in harvest rates and winter weather conditions.

LITERATURE CITED

Ballard, W. B., H. A. Whitlaw, S. J. Young, R. A. Jenkins, and G. J. Forbes. 1999. Predation and survival of white-tailed deer fawns in northcentral New Brunswick. Journal of Wildlife Management 63:574-579.

Beringer, J., L. P. Hansen, W. Wilding, J. Fischer, and S. L. Sheriff. 1996. Factors affecting capture myopathy in white-tailed deer. Journal of Wildlife Management 60:373-380.

Brinkman, T. J. 2003. Movement and mortality of white-tailed deer in southwest Minnesota. M.S. Thesis, South Dakota State University, Brookings, USA.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, J. D. Erb, and B. S. Haroldson. 2002. A vehicle-mounted radiotelemetry antenna system design. Wildlife Society Bulletin 30:258-262.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, B. S. Haroldson, and R. G. Osborn. 2005. Movement of female white-tailed deer: effects of climate and intensive row-crop agriculture. Journal of Wildlife Management 69:1099-1111.

Brinkman, T. J., J. A. Jenks, C. S. DePerno, B. S. Haroldson, and R. G. Osborn. 2004. Survival of white-tailed deer in an intensively farmed region of Minnesota. Wildlife Society Bulletin 32:726-731.

Bryce, S., J.M. Omernik, D.E. Pater, M.Ulmer, J. Schaar, J.Freeouf, R.Johnson, P. Kuck, and S.H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/habitat/ndsdeco/index.htm>. Accessed 26 July 2011.

Burris, B. M. 2005. Seasonal movements of white-tailed deer in eastern South Dakota and southwestern Minnesota relative to traditional ranges and management unit boundaries. M. S. Thesis, South Dakota State University, Brookings, USA.

Clover, M. R. 1956. Single gate deer trap. California Fish and Game 42:199-201.

Cooch, E., and G. C. White. 2006. Program Mark: a gentle introduction. Fifth edition. Department of Natural Resources, Cornell University, Ithaca, NY, USA.

DelGuidice, G. D., B. A. Mangipane, B. A. Sampson, and C. O. Kochanny. 2001. Chemical immobilization, body temperature, and post-release mortality of white-tailed deer captured by Clover trap and net-gun. Wildlife Society Bulletin 29:1147-1157.

DelGiudice, G. D., M. R. Riggs, P. Joly, and W. Pan. 2002. Winter severity, survival, and cause-specific mortality of female white-tailed deer in north-central Minnesota. Journal of Wildlife Mangement 66:698-717.

DePerno, C. S., J. A. Jenks, S. L. Griffin, and L. A. Rice. 2000. Female survival rates in a declining white-tailed deer population. The Wildlife Society Bulletin 28:1030-1037.

DePerno, C. S., J. A. Jenks, and S. L. Griffin. 2003. Multidimensional cover characteristics: is variation in habitat selection related to white-tailed deer sexual segregation. Journal of Mammalogy 84:1316-1329.

Dusek, G. L., A. K. Wood, and S. T. Stewart. 1992. Spatial and temporal patterns of mortality among female white-tailed deer. Journal of Wildlife Management 56:645-650.

Fuller, T. K. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildlife Monographs 110:1-37.

Grassel, S. M. 2000. Evaluation of methodology used to estimate population size, sex and age ratios, and mortality of white-tailed and mule deer in the Missouri River Breaks Region of South Dakota. Thesis, South Dakota State University, Brookings, USA.

Grovenburg, T. W. 2007. Movement patterns of white-tailed deer in east central South Dakota relative to winter ranges and management unit boundaries. M. S. Thesis, South Dakota State University, Brookings, USA.

Grovenburg, T. W., J. A. Jenks, R. W. Klaver, C. C. Swanson, C. N. Jacques, and D. Todey. 2009. Seasonal movements and home ranges of white-tailed deer in north-central South Dakota. Canadian Journal of Zoology 87:876-885.

Grovenburg, T.W., C.C. Swanson, C.N. Jacques, C.S. Deperno, R.W. Klaver, and J.A. Jenks. 2011. Female white-tailed deer survival across ecoregions in Minnesota and South Dakota. The American Midland Naturalist 165:426-435.

Hanley, T. A., C. T. Robbins, and D. E. Spalinger. 1989. Forest habitats and the nutritional ecology of sitka black-tailed deer: a research synthesis with implications for forest management. United States Department of Agriculture, Forest Service, General Technical Report PNW-GTR-230, Portland, Oregon.

Jacques, C. N., J. A. Jenks, C. S. DePerno, J. D. Sievers, T. W. Grovenburg, T. J. Brinkman, C. C. Swanson, and B. A. Stillings. 2009. Evaluating ungulate mortality associated with helicopter net-gun captures in the northern Great Plains. Journal of Wildlife Management 73:1282-1291.

Johnson, J. R., and G. E. Larson. 1999. Grassland plants of South Dakota and the Northern Great Plains. South Dakota State University College of Agriculture & Biological Sciences, South Dakota Agriculture Experiment Station, Brookings, USA.

Johnson, R. R., K. F. Higgins, M. L. Kjellsen, and C. R. Elliott. 1997. Eastern South Dakota wetlands. Brookings: South Dakota State University. Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/wetlands/eastwet/index.htm>. Accessed 9 July 2011.

Jones, M. L., N. E. Mathews, and W. F. Porter. 1997. Influence of social organization on dispersal and survival of translocated female white-tailed deer. Wildlife Society Bulletin 25:272-278.

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistics Association 53:457-481.

Kernohan, B. J., J. J. Millspaugh, J. A. Jenks, and D. E. Naugle. 1998. Use of an adaptive kernel home-range estimator in a GIS environment to calculate habitat use. Journal of Environmental Management 53:83-89.

Lamoureux, J., M. Crete, and M. Belanger. 2001. Effects of reopening hunting on survival of white-tailed deer, *Odocoileus virginianus*, in the Bas-Saint-Laurent region, Quebec. Canadian Field Naturalist 115:99-105.

Lewis, T. L., and O. J. Rongstad. 1998. Effects of supplemental feeding on white-tailed deer, *Odocoileus virginianus*, migration and survival in northern Wisconsin. CanadianField Naturalist 112:75-81.96.

Matschke, G. H., K. A. Fagerstone, F. A. Hayes, W. Parker, D. O. Trainer, R. F. Harlow, and V. F. Nettles. 1984. Population influences. Pages 168-188 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

McDonald, P., R. A. Edwards, and J. F. D. Greenhalgh. 1973. Animal nutrition. Hafner Press, New York, New York, USA.

Mech, D. L. 1984. Predators and predation. Pages 189-200 *in* L. K. Halls, editor. White-tailed Deer: Ecology and Management. Stackpole Books, Harrisburg, Pennsylvania, USA.

National Climatic Data Center. 2011. Record of Climatological Observations. <http://www7.ncdc.noaa.gov/IPS/coop/coop.html>. Accessed 9 May 2011.

Nelson, M. E., and L. D. Mech. 1986. Mortality of white-tailed deer in northeastern Minnesota. Journal of Wildlife Management 50:691-698.

Nixon, C. M., L. P. Hansen, P. A. Brewer, J. E. Chelsvig, T. L. Esker, D. Etter, J. B. Sullivan, R. G. Koerkenmeier, and P. C. Mankin. 2001. Survival of white-tailed deer in intensively farmed areas of Illinois. Canadian Journal of Zoology 79:581-588.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7-15.

Porter, W. F., H. B. Underwood, and J. L. Woodard. 2004. Movement behavior, dispersal, and the potential for localized movement of deer in a suburban environment. Journal of Wildlife Management 68:247-256.

Robbins, C. T. 2001. Wildlife feeding and nutrition. Academic Press, Inc., San Diego, California, USA.

SAS Institute. 2000. SAS/STAT user's guide, version 8. SAS Institute, Cary, North Carolina, USA.

Severinghaus, C. A. 1949. Tooth development and wear as criteria of age in white-tailed deer. Journal of Wildlife Management 13:195-216.

Severinghaus, C. A. and E. L. Cheatum. 1956. Life and times of the white-tailed deer. Pages 57-186 *in* W. P. Taylor, editor. The Deer of North America. Stackpole Books. Harrisburg, Pennsylvania, USA.

Smith, V. J., J. A. Jenks, C. R. Berry, Jr., C. J. Kopplin, and D. M. Fecske. 2002. The South Dakota Gap Analysis Project. Final Report. Research Work Order No. 65. Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, S.D, USA.

South Dakota Department of Game, Fish and Parks. 2010*a*. 2009 Big game harvest projections. South Dakota Game Report No 2011-05. Division of Wildlife, South Dakota Department of Game, Fish and Parks, Pierre, USA.

South Dakota Department of Game, Fish and Parks. 2010*b*. South Dakota 2010 Hunting Atlas. Midstates Printing Inc. Pierre, USA.

South Dakota Department of Game, Fish and Parks. 2011. 2010 Big game harvest projections. South Dakota Game Report No 2011-06. Division of Wildlife, South Dakota Department of Game, Fish and Parks, Pierre, USA.

South Dakota Office of Climatology. 2011. South Dakota climate and weather. <http://climate.sdstate.edu>. Accessed 2 May 2011.

Swanson, C. C. 2005. Movement and association of white-tailed deer in southwest Minnesota. M. S. Thesis, South Dakota State University, Brookings, USA.

United States Department of Agriculture. 2009. National Agricultural Imagery Program (NAIP). Farm Service Agency. <http://www.fsa.usda.gov/FSA/. apfoapp?area=home&subject=prog&topic=nai>. Accessed 8 February 2009.

U.S. Geological Survey, Gap Analysis Program (GAP). 2010. National Land Cover, version 1. <http://gapanalysis.usgs.gov/data/land.cover.data>. Accessed 23 May 2011.

Van Deelen, T. R., H. Campa III, J. B. Haufler, and P. D. Thompson. 1997. Mortality patterns of white-tailed deer in Michigan's upper peninsula. Journal of Wildlife Management 61:903-910.

Whitlaw, H. A., W. B. Ballard, D. L. Sabine, S. J. Young, R. A. Jenkins, and G. J. Forbes. 1998. Survival and cause-specific mortality rates of adult white-tailed deer in New Brunswick. Journal of Wildlife Management 62:1335-1341.

White, G. C., and K. P. Burnham. 1999. Program Mark: Survival estimation from populations of marked animals. Bird Study 46 Supplement, 120-130.

White, G. C., R. A. Garrott, R. M. Bartmann, L. H. Carpenter, and A. W. Alldredge. 1987. Survival of mule deer in northwest Colorado. Journal of Wildlife Management 51:852-859.

Table 3-1. Annual survival rates for radiocollared white-tailed deer in Clark County, South Dakota, 2009 and 2010.

	2009	2010	Overall (24 month)
Number at-risk	26	37	43
Number of Deaths	5	12	17
Number Censored	0	0	0
Survival Rate	0.78	0.70	0.55
SE	0.079	0.075	0.081
CI lower	0.594	0.539	0.393
CI upper	0.90	0.827	0.699

Table 3-2. Seasonal survival rates for radiocollared white-tailed deer in Clark County, South Dakota, 2009 – 2010.

	2009			2010		
Season[a]	Post-hunt	Pre-hunt	Hunting	Post-hunt	Pre-hunt	Hunting
Number at-risk	26	25	34	37	36	36
Number of Deaths	1	0	3	3	0	10
Number Censored	0	0	0	0	0	0
Survival Rate	0.96	1	0.84	0.94	1	0.72
SE	0.038	*	0.073	0.038	*	0.075
CI lower	0.772	1	0.643	0.803	1	0.556
CI upper	0.995	1	0.939	0.986	1	0.844

[a]Seasonal intervals = Post hunt (1 February – April 30), Pre-hunt (1 May – 10 September), and Hunting (11 September – 31 January).

*No animals died during these seasonal intervals.

Table 3-3. Seasonal, cause-specific mortality for radiocollared white-tailed deer Clark County, South Dakota, 2009 – 2011.

Cause of Mortality	Pre-hunt[a]	Hunting[a]	Post-hunt[a]	Totals
Harvest	0	11	0	11
Predation	0	0	2	2
Disease	0	1	1	2
Unknown	0	1	1	2

[a]Seasonal intervals = Post hunt (1 February – April 30), Pre-hunt (1 May – 10 September), and Hunting (11 September – 31 January).

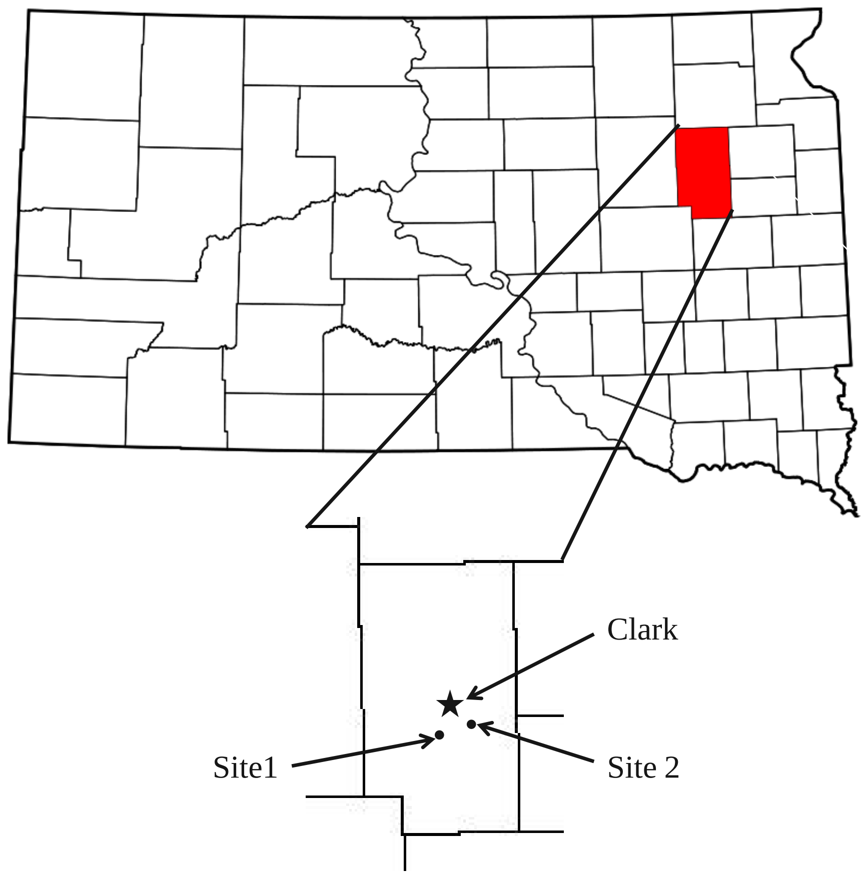


Figure 3-1. Clark County study area for white-tailed deer in eastern South Dakota, 2009-2011 with designated helicopter capture sites.

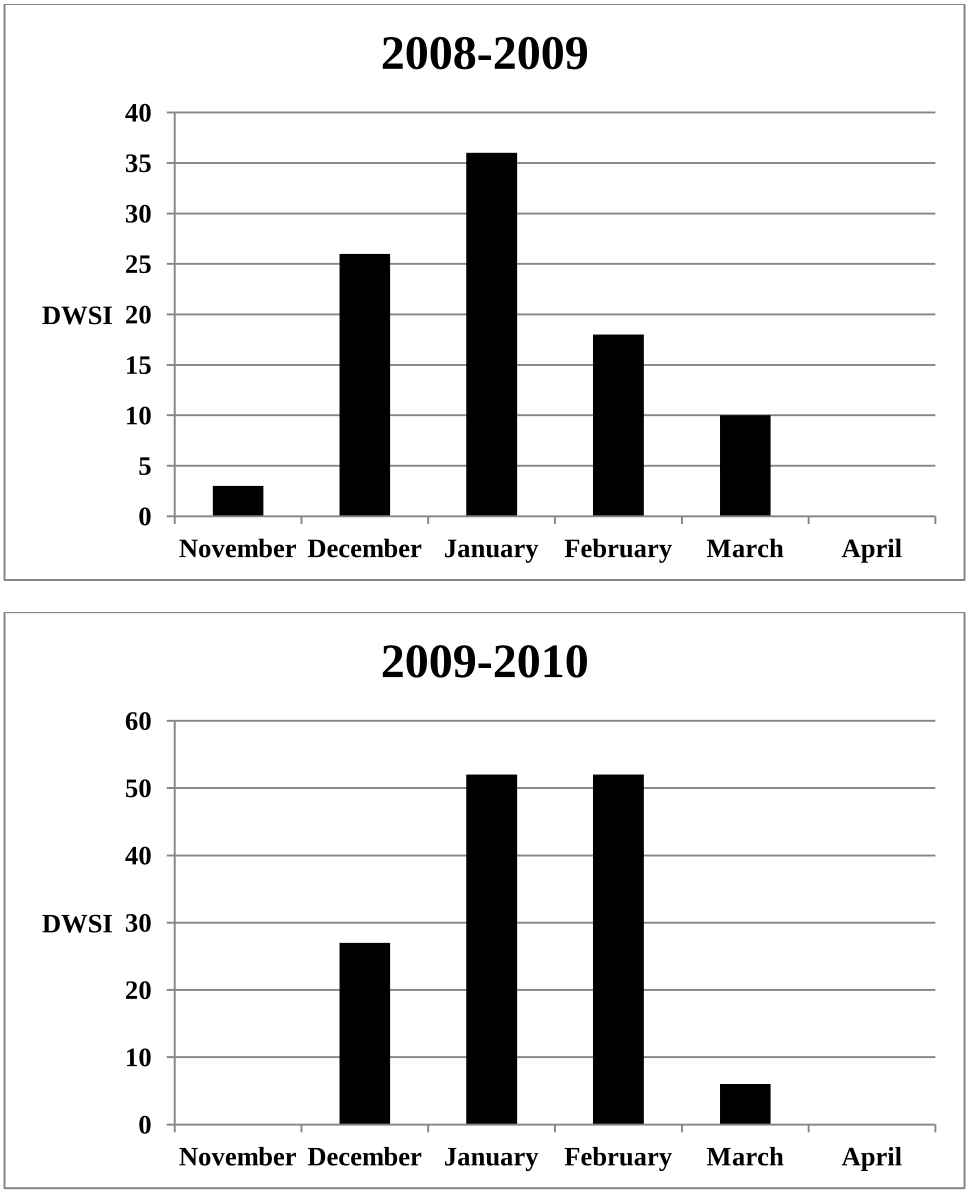


Figure 3-2. Monthly deer winter severity indices (DWSI) for Clark County, South Dakota. We assigned one point for each day mean temperature was $\leq$ -7 ^{o}C and an additional point for each day snow depth was $\geq$ 35.0 cm; National Climatic Center of Climatology 2011.

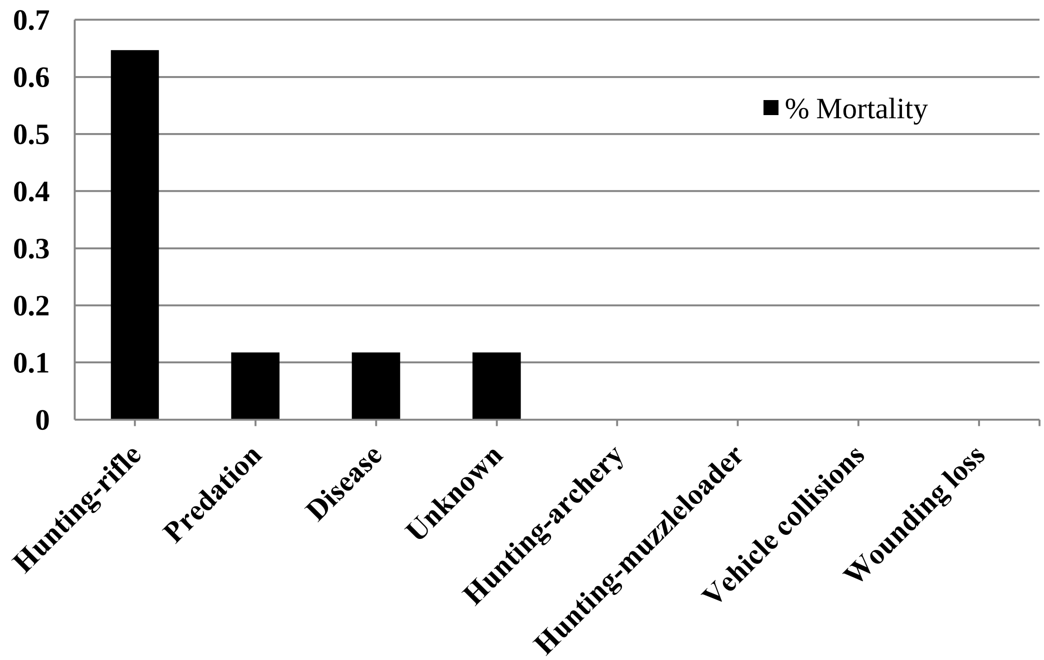


Figure 3-3. Percent cause-specific mortality (n= 17) of radiocollared female white-tailed deer in eastern South Dakota.

CHAPTER 4: RESOURCE SELECTION OF WHITE-TAILED DEER IN THE PRAIRIE POTHOLE REGION OF EASTERN SOUTH DAKOTA

ABSTRACT Winter and summer resource selection and habitat use of white-tailed deer in eastern South Dakota were studied from 2009 - 2011. Thirteen summer and 15 winter habitat categories were mapped during summer 2009 and 2010 and winter 2009 and 2010 encompassing 58 winter and 61 summer home ranges of 42 radiocollared female white-tailed deer. We collected 4,688 summer locations and 1,826 winter locations via radio telemetry. Habitat use differed slightly between seasons with CRP grasslands, standing corn, and wetlands being used the most throughout summer home ranges and CRP grasslands, trees, and wetlands being used the most in winter. We evaluated winter and summer resource selection using design II and III analyses. Analysis using design II demonstrated that trees ($\hat{w}$ = 3.81) were selected with higher probability ($P<0.10$) when compared to all of the other habitats available for both winter and summer. During winter, Conservation Reserve Program grasslands ($\hat{w}$ = 1.45) and standing corn ($\hat{w}$ = 2.89) were selected with greater probability than other habitats. Design III analysis indicated that extensive variation existed among animals and proportions of habitat categories found within individual home ranges; however, the model using all animals indicated that trees ($\hat{w}$ = 2.67) were selected with higher probability ($P<0.10$) than other habitats.

INTRODUCTION

White-tailed deer (*Odocoileus virginianus)* select suitable habitats that satisfy survival requirements (Beier and McCullough 1990). Thus, understanding habitat selection can help predict effects of habitat change on ecological processes and enable protection of key habitat types and vegetative cover (Author et al. 1996, Grovenburg et al. 2011). Adequate quantities of suitable resources must exist to sustain white-tailed deer populations (Manly et al. 2002), provide opportunities for successful reproduction (Mysterud and Ims 1998), and maintain overall fitness of the species (Grovenburg 2007).

Resource availability is not uniform in nature and therefore, use may change as the availability of resources changes. Selection occurs when resources are used disproportionately to their availability (Manly et al. 2002). Definitions regarding selection, usage, and availability are defined by Manly et al. (2002) as the act in which an animal selects a resource, and usage is defined as the amount of resource that is being used by an animal or population of animals, in a set period of time. Availability is defined as the amount of that resource accessible to an individual or population of animals during the same time period.

Resource selection occurs at various levels in a hierarchical fashion and because the criterion for selection varies, the level must be specified by the researcher (Orians and Wittenberger 1991). Multiscale habitat selection studies have become more popular and in some cases recommended (Ottis 1997, Manly et al. 2002, Meyer and Thuiller 2006). Various habitat selection categories do exist and may be discrete (e.g., plowed field, standing corn, wetland) or continuous (e.g., tree density, distance to cover, canopy height; Manly et al. 2002). Determining habitats that are being selected will verify long-term resource needs of populations and document what resources are most important to the population (Manly et al. 2002, Osko et al. 2004, Grovenburg et al. 2011).

Thorough research has been conducted on winter and summer habitat use by white-tailed deer across the northern regions of North America in Michigan (Ozoga and Gysel 1972, Beier and McCullough 1990), Minnesota (Wetzal et al. 1975, Kohn and Mooty 1971, Mooty et al. 1987), Wisconsin (Murphy et al. 1985, Larson et al. 1978), Illinois (Rosenberry and Woolf 1998), Montana (Martinka 1968, Singer 1979, Mundinger 1980, Dusek et al. 1989), and South Dakota (Sparrowe and Springer 1970, Kramlich 1985, Kennedy 1992, Gould and Jenkins 1993, Kernohan et al. 1996). Results indicated that snow cover had the most influence on which habitats deer use in winter (Moen 1978, Parker et al. 1984). In some areas during mild winters, deer use habitats that had quality forages present and during severe winters deer conserved energy by utilizing habitat that provided good thermal cover (Moen 1978, Pauley et al. 1993). During summer, deer intensively used habitats that had high quality forages available and suitable escape cover, such as agricultural row crops (i.e., corn), treebelts, grasslands, and wetlands (Kohn and Mooty 1971, Murphy et al. 1985, Kramlich 1985, Gould and Jenkins 1993, Kernohan et al. 1996).

Habitat use by white-tailed deer has been studied extensively, however; limited information exists regarding resource selection within the winter and summer ranges of white-tailed deer in the Northern Great Plains. During a mild winter, Grovenburg et al. (2010) documented winter resource selection ratios for east central South Dakota and found that no single habitat was selected when habitat availability was defined at the population level and habitat use was measured for each individual animal. Extensive variation existed when both the availability and use of habitat were measured for each animal. Therefore, resource selection remains poorly understood, especially during severe winters or during summer throughout the Northern Great Plains. An understanding of the importance of habitat selection of deer will allow managers to predict the effects of human disturbance and habitat modification on future habitat-use patterns for white-tailed deer (Calenge and Dufour 2006). We hypothesized that (1) white-tailed deer would select suitable thermal cover (i.e., wetlands and trees) during severe winters; and (2) white-tailed deer would select areas that have high quality forages available during the summer months (i.e., agricultural row crops). Knowledge gained from this study will help managers understand the functional role of individual habitat types pertaining to the ecology and management of white-tailed deer.

STUDY AREA

We studied adult female white-tailed deer from January 2009 to February 2011 in Clark County, South Dakota (Figure 1), which comprised an area of 1,294 km^2. Mean annual (30-yr) precipitation was 56.2 cm and mean (30-yr) monthly temperature ranged from -11.9^{o} C to 21.8^{o} C (South Dakota Office of Climatology 2011). Clark County is located in the level III ecoregion of the Northern Glaciated Plains (Bryce et al. 1998) and lies in the Prairie Pothole Region (Johnson et al. 1997). Soils of the study area were composed of glacial till and topography was flat to gently rolling terrain intermixed with numerous semi-permanent, temporary, and seasonal wetlands that were formed by glaciers (Bryce et al. 1998, Johnson et al. 1997). The glacial till soil is fertile and the predominant land use in Clark County is agriculture with cultivated land and pasture/hay land comprising 45.2% and 19.0% of total land use, respectively. Wetlands and grasslands comprised 11.6% and 11% of the county, respectively (U.S. Geological Survey 2010). Within this area, cultivated crops, including corn (*Zea mays*), soybeans (*Glycine max*) and wheat (*Triticum aestivum*) comprised 48% of the landscape and pasture land comprised 8% of the landscape. Wetlands comprised 23% of the landscape, and CRP grasslands covered 15% of the landscape. Both woodland plantings and shelterbelts, and developed areas covered 3% of the area (Smith et al. 2002). Land use alterations were commonly occurring throughout the duration of this study because of above average precipitation and agricultural draining (i.e., tiling) practices.

Native warm and cool season grasslands that were enrolled in the Conservation Reserve Program (CRP) were dominated by big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), western wheatgrass (*Elymus smithii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*) and smooth brome (*Bromus inermis*). Wetland vegetation was dominated by cattails (*Typha* spp.), sedges (*Carex* spp.), rushes (*Juncus* spp.), reed canarygrass (*Phalaris arundinacea),* prairie cordgrass (*Spartina pectinata*), and common reed (*Phragmites australis*). Woodlands and shelterbelts were primarily comprised of American elm (*Ulmus americana*), green ash (*Fraxinus pennslyvanica*), eastern cottonwood (*Populus deltoides*), boxelder (*Acer negundo)* and eastern red ceder (*Juniperus virginiana*: Johnson and Larson 1999).

METHODS

Capture and Handling

From 22 January to 15 February 2009 and from 7 January to 25 February 2010 we captured white-tailed deer using modified Clover traps (Clover 1956) and helicopter net guns (DelGuidice et al. 2001) in the southern portion of Clark County (Figure 1). We directed trapping and net gunning efforts towards adult females because they play a significant role in reproduction and normally dominate white-tailed deer harvests in eastern South Dakota (South Dakota Department of Game, Fish and Parks 2010). All captured deer were sexed and aged as fawn (~8-10 months), yearling (8 – 18 months), or adult (> 1.5 years) based on tooth replacement and incisor wear (Severinghaus 1949, Severinghaus and Cheatum 1956). We ear-tagged all animals with metal and plastic ear-tags (Hasco Tag Company, Dayton, KY, USA) and fitted adult females with VHF (Very High Frequency) radiocollars (Advanced Telemetry Systems, Inc., Isanti, MN) that were equipped with mortality sensors that activated if the collar remained still for 8 hours. Concerns regarding animal welfare were addressed by checking traps daily at first light, manually restraining and blindfolding all captured individuals, and monitoring rectal temperatures as an indication of stress (DelGuidice et al. 2001). All methods described in this research were approved by the Institutional Animal Care and Use Committee (IACUC, Approval No. 08-A028) at South Dakota State University.

Monitoring Radiocollared Adult Females

We monitored all radiocollared deer 2-3 times weekly for survival and we performed ground triangulation using a vehicle mounted “null-peak” antenna system to obtain location estimates (Brinkman et al. 2002). We used an electronic digital compass (C100 Compass Engine, KVH Industries, Inc., Middletown, RI, USA; Cox et al. 2002) that was connected to the mast of the null-peak antenna system to generate directional bearings; this unit had an estimated azimuth accuracy of +/-1^{o} and we calibrated it every six months. We took four to six directional bearings from established telemetry stations for each location. We entered bearings into the LOCATE III (Nams 2006) program to estimate locations and error polygons. All locations included a minimum of three azimuths and we excluded locations with 95% error ellipses ≥20 ha from analyses (Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2010). We never located animals on successive days and tracked them at different times of the day, including nights, to maintain temporal independence and to ensure accurate home range estimates (Kernohan et al. 1996). We excluded animals that experienced mortality ≤26 days post capture from analyses (Beringer et al. 1996). We imported locations into ArcView (ESRI, Inc., Redlands, CA) and used the Home Range Extension (HRE) (Rodgers and Carr 1998) to calculate 50% (core area) and 95% seasonal home ranges (fixed kernel). We used least-squares cross-validation to estimate the smoothing parameter (LSCV; Seaman et al. 1999).

We calculated deer winter severity indices (DWSI; Brinkman et al. 2005) for the Clark County area during the winter of 2008-09 and 2009-10. We assigned one point for each day mean temperature was ≤ -7 ^{o}C and an additional point for each day snow depth was ≥ 35.0 cm (Brinkman et al. 2005) during the months of October-April (National Climatic Data Center 2011).

Resource Selection Analysis

We imported individual location estimates and home range polygons into ArcMap 9.3 and overlaid them on 2008 National Land Cover Data (United States Department of Agriculture 2009). We ground-verified individual habitat and annual land use and created unique maps for winter 2009 and 2010 and summer 2009 and 2010. Locations in which the error polygon overlapped >1 habitat type were eliminated (White and Garrott 1990, Nams 1999). Geoprocessing was performed in ArcMap 9.3 to calculate resource use and availability for each season (n=4) analyzed.

We calculated resource selection using design II and III and set α=0.10 (Klaver et al. 2008). Using design II we identified individual habitat use and defined habitat availability at the population level. For design III, we identified individual habitat use and availability (Manly et al. 2002). We used program R version 2.12.1 (R Development Core Team 2010) with the adehabitat package (Calenge 2006) to calculate selection ratios and chi-square tests for habitats selected by white-tailed deer in the Clark County study area. Selection ratios were analyzed to determine whether selection was positive, negative, or neutral for individual habitat types. Selection of habitat was indicated if selection ratios ($\hat{w}$) differed significantly from 1; if confidence intervals for w_i did not contain the value 1 and the upper limit was <1 the habitat type was considered avoided whereas if the confidence interval for w_i did not contain the value 1 and the lower limit was >1 then the habitat type was considered selected (Manly et al. 2002). We also used eigenanalysis of selection ratios to determine variation in cover type selection among individual deer. We performed this analysis to determine if some habitat types were strongly selected by some deer and weakly selected by others (Calenge and Dufour 2006).

RESULTS

We captured and radiocollared 30 adult (>1.5 years) and 13 yearling (8-18 months) female deer and ear-tagged an additional 20 deer (1 adult buck, 1 yearling buck, 9 male fawns, 9 female fawns; Appendix A, B) during January-February 2009 (n=26; Appendix A) and January-February 2010 (*n*=17; Appendix B) in Clark County in eastern South Dakota (Figure 1). We captured 25 female white-tailed during helicopter net-gun operations and 44 during Clover trapping operations. We collected a total of 6,877 deer locations with a mean 95% error ellipse of 1.8 ha from January 2009-January 2011 in Clark County, South Dakota.

Winter 2008-2009 snowfall was 130 cm, 38.5% > normal, and 2009-2010 snowfall was 99 cm, 19.2% > normal. Mean monthly temperatures were 1.3^{o} C below normal for both winters (South Dakota Office of Climatology 2011). Average DWSIs for winter 2008-2009 and 2009-2010 (Figure 2) were 93.0 and 137.0, respectively, for Clark County.

For winter 2009, we mapped a total of 903 individual habitat polygons using 15 habitat categories (Table 1) encompassing winter home ranges of 25 female white-tailed deer. We collected 585 locations between 16 February and 6 April and determined that the four habitat types with highest habitat use were CRP (33.7%), wetlands (21.0%), cut corn (10.9%) and trees (8.4%) (Figure 3).

For summer 2009, we mapped a total of 1,276 individual habitat polygons using 13 habitat categories (Table 1) encompassing summer home ranges of 25 female white-tailed deer. We collected 1,893 individual locations between 7 April and 2 January and determined that wetlands (29.2%), standing corn (19.9%), CRP (17.7%), and trees (10.9%) were the four habitat types with highest use by deer (Figure 3).

For winter 2010, we mapped a total of 1,558 individual habitat polygons using 14 different habitat categories (Table 1) encompassing winter home ranges of 36 female white-tailed deer. We collected 1,102 individual locations between 2 January and 7 April and determined that CRP (24.3%), wetlands (23.2%), trees (20.9%) and cut corn (12.4%) were the four habitat types with highest use by deer (Figure 4).

For summer 2010, we mapped a total of 1,933 individual habitat polygons using 11 habitat categories encompassing summer home ranges of 36 female white-tailed deer. We collected 2,424 individual locations between 8 April and 22 December and determined that wetlands (23.3%), standing corn (18.6%), trees (17.3%) and CRP (17.2%) were the four habitat types with highest use by deer (Figure 4). We calculated available habitat in each 95% home range polygon for resource selection analyses. Throughout the study, habitat availability encompassing the minimum convex polygon for all radiocollared female white-tailed deer varied (P=0.023) each season (Table 1).

Design II

We determined that deer were not using resources in the same proportions as available habitats and they were not selecting habitat in proportion to its availability for all seasons analyzed ($P<0.001$). In winter 2009, deer avoided cut corn ($\hat{w}$ =0.609, CI = 0.338 - 0.879), soybean stubble ($\hat{w}$ =0.528, CI = 0.122 - 0.934) and rye (*Secale cereal*) ($\hat{w}$ =0.265, CI = 0.000 - 0.738). Wetlands ($\hat{w}$ =0.968, CI = 0.635 - 1.30), pasture land ($\hat{w}$ =0.761, CI = 0.16 - 1.363), wheat stubble ($\hat{w}$ =1.034, CI = 0.187 - 1.88), short grass ($\hat{w}$

=0.82, CI = 0.067 - 1.574), standing corn (ŵ =0.907, CI = 0.000 - 2.025), tall grass (ŵ =1.303, CI = 0.000 - 2.995), and roads/development (ŵ =0.492, CI = 0.000 - 1.139) were used in proportion to their availability by deer. We documented selection by deer for CRP (ŵ =1.601, CI = 1.077 - 2.126) and trees (ŵ =2.426, CI = 1.327 - 3.525; Figure 5). In summer 2009, deer avoided wheat (ŵ =0.348, CI = 0.051 - 0.645) and standing soybeans (ŵ =0.398, CI = 0.234 - 0.562) and used wetlands (ŵ =1.336, CI = 0.897 - 1.774), pasture land (ŵ =0.636, CI = 0.189 - 1.082), CRP (ŵ =1.304, CI = 0.737- 1.871), short grass (ŵ =0.747, CI = 0.000 - 1.645), standing corn (ŵ =1.075, CI = 0.706 - 1.445), tall grass (ŵ =0.852, CI = 0.000 - 1.969), alfalfa (ŵ =1.243, CI = 0.217 - 2.27), and roads/development (ŵ =0.825, CI = 0.015 - 1.634) in proportion to their availability. We documented selection for trees (ŵ =3.81, CI = 2.561 - 5.059; Figure 5).

In winter 2010, deer avoided soybean stubble (ŵ =0.489, CI = 0.288 - 0.691), pasture land (ŵ =0.257, CI = 0.03 - 0.485), wheat stubble (ŵ =0.034, CI = 0.000 - 0.098), tall grass (ŵ =0.144, CI = 0.000 - 0.533), and plowed fields (ŵ =0.223, CI = 0.042 - 0.403) based on availability. We documented no selection or avoidance for wetlands (ŵ =0.933, CI = 0.72 - 1.145), cut corn (ŵ =0.799, CI = 0.59 - 1.007), short grass (ŵ =2.114, CI = 0.631 - 3.597), rye (ŵ =0.827, CI = 0.000 - 1.738), alfalfa (ŵ =0.628, CI = 0.000 - 1.569) or roads/development (ŵ =0.610, CI = 0.000 - 1.429). We documented selection for trees (ŵ =5.864, CI = 4.444 - 7.284), CRP (ŵ =1.304, CI = 1.027 - 1.581), and standing corn (ŵ =4.772, CI = 2.498 - 7.046); Figure 6). In summer 2010, deer avoided wheat (ŵ =0.323, CI = 0.027 - 0.619), pasture land (ŵ =0.514, CI = 0.233 - 0.794), and standing soybeans (ŵ =0.438, CI = 0.309 - 0.568) based on their availability. We documented no selection or avoidance for wetlands ($\hat{w}$ =0.916, CI = 0.692 - 1.14), short grass ($\hat{w}$ =0.90, CI = 0.255 - 1.544), standing corn ($\hat{w}$ =1.098, CI = 0.77 - 1.426), tall grass ($\hat{w}$ =1.552, CI = 0.625 - 2.478), alfalfa ($\hat{w}$ =0.922, CI = 0.000 - 1.974), or roads/development ($\hat{w}$ =0.636, CI = 0.019 - 1.253). We documented selection by deer for trees ($\hat{w}$ =6.225, CI = 4.846 - 7.605) and CRP ($\hat{w}$ =1.70, CI = 1.073 - 2.327); Figure 6).

Design III

We determined that deer were not selecting habitat in proportion to its availability for all seasons analyzed ($P<0.001$). In winter 2009, deer avoided rye stubble ($\hat{w}$ =0.489, CI = 0.000 - 0.985) and tall grass ($\hat{w}$ =0.649, CI = 0.309 - 0.989). We documented no selection or avoidance for wetlands ($\hat{w}$ =0.981, CI = 0.661 - 1.301), pasture land ($\hat{w}$ =0.844, CI = 0.475 - 1.212), wheat stubble ($\hat{w}$ =0.788, CI = 0.536 - 1.039), short grass ($\hat{w}$ =0.859, CI = 0.147 - 1.571), standing corn ($\hat{w}$ =0.692, CI = 0.000 - 1.472), cut corn ($\hat{w}$ =0.863, CI = 0.626 - 1.10), CRP ($\hat{w}$ =1.151, CI = 0.91 - 1.392), soybean stubble ($\hat{w}$ =0.803, CI = 0.526 - 1.081), or roads/development ($\hat{w}$ =0.744, CI = 0.000 - 1.688). We documented selection for trees ($\hat{w}$ =2.142, CI = 1.068 - 3.216; Figure 7). In summer 2009, deer avoided wheat ($\hat{w}$ =0.623, CI = 0.349 - 0.898), pasture land ($\hat{w}$ =0.532, CI = 0.359 - 0.706), tall grass ($\hat{w}$ =0.492, CI = 0.114 - 0.869) and standing soybeans ($\hat{w}$ =0.532, CI = 0.376 - 0.688). We documented no selection or avoidance for wetlands ($\hat{w}$ =1.157, CI = 0.855 - 1.458), CRP ($\hat{w}$ =1.057, CI = 0.764 - 1.351), short grass ($\hat{w}$ =0.691, CI = 0.249 - 1.133), standing corn ($\hat{w}$ =1.192, CI = 0.949 - 1.434), alfalfa ($\hat{w}$ =0.89, CI = 0.489 - 1.292), or roads/development ($\hat{w}$ =0.951, CI = 0.22 - 1.683). We documented selection by deer for trees ($\hat{w}$ =2.612, CI = 1.719 - 3.504; Figure 7).

In winter 2010, deer avoided rye stubble ($\hat{w}$ =0.427, CI = 0.113 - 0.743), pasture land ($\hat{w}$ =0.418, CI = 0.122 - 0.714), plowed fields ($\hat{w}$ =0.258, CI = 0.067 - 0.449), and wheat stubble ($\hat{w}$ =0.061, CI = 0.000 - 0.213). We documented no selection or avoidance for wetlands ($\hat{w}$ =0.89, CI = 0.713 - 1.068), short grass ($\hat{w}$ =1.084, CI = 0.374 - 1.794), standing corn ($\hat{w}$ =2.771, CI = 0.874 - 4.668), tall grass ($\hat{w}$ =0.301, CI = 0.000 - 1.024), alfalfa ($\hat{w}$ =1.304, CI = 0.000 - 3.189), cut corn ($\hat{w}$ =0.894, CI = 0.709 - 1.077), CRP ($\hat{w}$ =0.888, CI = 0.746 - 1.029), soybean stubble ($\hat{w}$ =0.763, CI = 0.468 - 1.057), or roads/development ($\hat{w}$ =0.976, CI = 0.000 - 2.20). We documented selection by deer for trees ($\hat{w}$ =3.118, CI = 1.965 - 4.27; Figure 8). In summer 2010, deer avoided wheat ($\hat{w}$ =0.465, CI = 0.177 - 0.753), pasture land ($\hat{w}$ =0.632, CI = 0.484 - 0.78), short grass ($\hat{w}$ =0.663, CI = 0.348 - 0.978), and standing soybeans ($\hat{w}$ =0.573, CI = 0.455 - 0.691). We documented no selection or avoidance for wetlands ($\hat{w}$ =0.975, CI = 0.823 - 1.127), CRP ($\hat{w}$ =1.196, CI = 0.925 - 1.467), tall grass ($\hat{w}$ =1.153, CI = 0.648 - 1.658), standing corn ($\hat{w}$ =0.987, CI = 0.799 - 1.175), alfalfa ($\hat{w}$ =0.835, CI = 0.186 - 1.484), or roads/development ($\hat{w}$ =0.632, CI = 0.085 - 1.178). We documented selection by deer for trees ($\hat{w}$ =3.317, CI = 2.438 - 4.195 Figure 8).

Eigenanalysis of selection ratios during the summer of 2009 and 2010 produced 2 factors that explained approximately 78.1% (55.2% for the first axis, and 22.9% for the second axis; Figure 9) and 84.8% (71.0% for the first axis, and 13.8% for the second axis; Figure 10), respectively, of the variation in selection. In the summer months, selection for trees explained 55.2% and 71.0% of the variability in habitat selection; indicating that selection strategies dominantly included trees and trees were selected by most deer throughout the summer. During the winter of 2009 and 2010, eigenanalysis of selection ratios produced 2 factors explaining approximately 74.1% (49.0% for the first axis, and 25.1% for the second axis; Fig. 11) and 86.5% (59.4% for the first axis, and 27.1% for the second axis; Fig. 12) of the variation. Selection for trees during the winter explained 49.0% and 59.4% of the variability in habitat selection. Thus, indicating trees were selected by the majority of animals studied; however, limited mixed selection strategies were documented and some animals selected more for CRP grasslands and standing corn during the winter months.

DISCUSSION

Quality and quantity of used habitats play an important role in the population dynamics of the animals. Animals likely select and use resources that satisfy life requirements and if these suitable resources are not available, survival and recruitment may be affected (Fagen 1988). When animals cannot substitute resource quantity for more quality and vice versa, animal use changes as population density changes. To predict these changes, we must thoroughly understand the mechanistic relationship that influences animal distribution and behavior. Evaluating the quantity and quality of wildlife habitat is an important component to land management because resource use is dependent on the habitat that is available (Hobbs and Hanley 1990).

Winter

White-tailed deer winter habitat use and selection in the Northern Great Plains of eastern South Dakota was similar to previous research conducted by Sparrow and Springer (1970), Kramlich (1985), Gould and Jenkins (1993), Kernohan et al. (1996) and

Grovenburg (2007). Deer consistently avoided soybean stubble, wheat stubble, pasture land, rye stubble and plowed fields. These habitat types provided no thermal cover or forage potential. Deep snow made these areas undesirable and deer generally used habitats that provided thermal cover and suitable forage (Habeck 1960, Verme 1965, Mooty et al. 1987). Deer intensively used CRP grasslands and wetlands during the winters of 2009 and 2010 and out of the 2,461 winter locations collected between 22 December and 7 April, 29% and 22.2% were located in CRP grasslands and wetlands, respectively.

Conservation Reserve Program grasslands covered 15% of the landscape in the Clark County area and use exceeded availability. During the winter months, design II and III analyses indicated that deer selected for CRP grasslands at the population level ($\hat{w}$ = 1.453); however, no selection or avoidance was documented at the individual level. We speculate resource selection and use of CRP grasslands during winters expressing high average DWSI (Figure 2) was a direct result of white-tailed deer trying to minimize thermoregulatory costs and an attempt to maintain body core temperatures from the thermal cover CRP grasslands provided (Gould and Jenkins 1993, DePerno et al. 2003, Grovenburg et al. 2010). Field observations indicated that deer utilized CRP grasslands the most where trees were present northwest of the grasslands, which blocked wind and blowing snow. Deer were often seen throughout the day in CRP grasslands especially during days of full sun and low wind.

A total of 22.2% of winter locations was located in wetlands and design II and III analyses indicated that deer selected for wetlands in proportion to their availability.

Wetlands served as excellent thermal cover throughout the winter months of our study. Wetland vegetation was composed mostly of cattails (*Typha* spp.) and phragmites (*Phragmites communis*), which provided suitable bedding areas that dramatically reduced wind velocities (Kramlich 1985, Kernohan et al. 1996). Elaborate trail systems were maintained by large wintering herds (100+) throughout numerous wetland complexes in the Clark County area. These trail systems likely provided increased mobility and decreased energy expenditure (Moen 1978). Sparrowe and Springer (1970), indicated that wetlands located in close proximity to a highly nutritious forage source (i.e., agricultural crops) were important to survival and maintenance of high density populations in eastern South Dakota. Wetland complexes served as a dominate source of cover in winter and our findings were similar to those of Sparrowe and Springer (1970), Kramlich (1985) and Kernohan et al. (1996).

We documented selection for trees in winters 2009 and 2010. Trees covered approximately 3% of the landscape in our study area; however, 14.7% of all locations collected in the winter months were located in this habitat. Design II and III analyses indicated that deer selected for trees at the population level ($\hat{w} = 4.145$) and at the individual level ($\hat{w} = 2.63$). Similar findings were reported for white-tailed deer habitat use and selection in the Northern Great Plains (Swenson et al. 1983, Peterson 1984, Kramlich 1985, Dusek et al. 1988, Nixon et al. 1991, Gould and Jenkins 1993, Kernohan 1994). Wooded areas were especially preferred when in close proximity to agricultural fields (i.e., standing or cut corn: Swenson et al. 1983). However, Grovenburg et al. (2010*a*) documented that deer in east central South Dakota, where forested habitats covered 2.3% of the landscape, selected for trees in proportion to their availability. These findings are contrary to our study and we speculate the lack of use for forested areas in east central South Dakota was a direct result from the mild winter conditions that existed. Because snow depth never exceeded 12.7 cm and only 21% of mean daily temperatures reached or exceeded ≤ -7^{o} C, deer were able to utilize alternate cover types, such as CRP grasslands and standing corn (Grovenburg et al. 2010*a*).

In our study, winter weather conditions were classified as severe, and trees were the most selected habitat throughout the winter months. We observed increased use of treebelts that were wider, resulting in less drifting of snow. Snow depth did have an effect on tree use; treebelts with snow depths >60 cm experienced little or no use. Our analyses also indicated that deer selected coniferous tree cover (i.e., *Juniperus virginiana)* during times of severe winter weather; likely for enhanced thermal cover and wind reduction (Habeck 1960, Verme 1965, Irwin 1974, Wetzal et al. 1975).

In our study area, during the winter months, standing corn covered < 1% of the landscape. Design II analysis indicated that deer selected for standing corn in 2010 at the population level ($\hat{w}$ =4.772) and similar documentation was reported by Grovenburg et al. (2010*a*) in east central South Dakota. Mysterud and Ims (1998) indicated that when food resources are limited in an animal's home range, the animal will adjust their home area to include the resources needed for survival, which was apparent in the Clark County study area. In some cases, individual home ranges were expanded to include small plots of standing corn; however, deer did not travel great distances (> 2 km) away from their historic winter ranges to seek out these resources. Standing corn fields represented ideal wintering habitat and provided critical food resources for winter survival (Sparrowe and Springer 1970, Peterson 1984, Kramlich 1985, Kernohan 1994, Grocenburg et al. 2010*a*).

Summer

Female white-tailed deer in the Northern Great Plains of eastern South Dakota used wetlands and standing corn extensively in the summer months and consistently avoided standing soybeans, wheat, and pasture land. Approximately 45.5% of all locations (*n*= 4,317) collected between 7 April and 22 December were located in wetlands or standing corn. Wetlands were utilized the most in summers 2009 (29.2%) and 2010 (23.2%) and served as excellent escape cover. Wetlands in the Clark County area covered much of the landscape (23%) and deer selected for wetlands in proportion to their availability. Similar findings were reported by Kramlich (1985), who demonstrated that wetlands were used in proportion to their occurrence in eastern South Dakota. Petersen (1984) explained the importance of wetlands in intensively farmed areas suggesting they provided essential cover especially where cover was limited.

Likewise, during the summer months in our study, standing corn covered much of the landscape (17.6%) and we documented that deer used standing corn in proportion to resource availability, especially after 10 July, when vertical height exceeded 1 meter (Nixon et al. 1991, Kernohan 1994). Kramlich (1985) indicated that corn was the most heavily used crop in eastern South Dakota. Kernohan (1994) noted that deer use of corn was related to temporal changes in cover (i.e., height and density) and forage characteristics and this was evident in our study as well. Furthermore, Grovenburg et al. (2010*b*) stated that white-tailed deer fawn use of standing corn was dependent on height of corn, and when corn reached an average height of 80-85 cm, fawns followed their dams into corn for cover. Kohn and Mooty (1971) documented that the availability of preferred forage species greatly influenced deer use and this may explain why deer in this area utilized standing corn intensively. Through anecdotal observations we noticed female white-tailed deer commonly used standing corn that was either surrounded by a wetland or in close proximity to a wetland. This combination of resources likely provided the essential requirements for white-tailed survival (Petersen 1984).

Deer also utilized trees and CRP grasslands during the summer months in the Clark County area. Approximately 17.45% and 14.1% of all locations (*n*= 4,317) collected between 7 April and 22 December were either in CRP grasslands or trees. Both trees and CRP grasslands served as excellent escape cover and provided suitable bedding areas, along with essential fawn rearing habitat (Grovenburg et al. 2010*b*). During the summer months, deer selected tree habitat at the population level ($\hat{w}$ = 5.017) and the individual level ($\hat{w}$ = 2.965). We speculate selection and use of trees in the Clark County area was attributed to the excellent cover this resource provided. Deer used trees intensively during spring (April – June) when wetland complexes were full of water and agricultural crops did not exceed 1 m in vertical height. Deer also used trees intensively in the fall (October - December) after crops were harvested and limited cover became available. Treebelts adjacent to preferred forages (i.e., agricultural crops) became activity centers because of proximity to the quality forage (Kramlich 1985). Similar research conducted by Zwank et al. (1979), Murphy et al. (1985), Gould and Jenkins

(1993), and Kernohan (1994) all reported intense use of wooded areas especially when cover was limited in the spring and fall months.

Conservation Reserve Program grasslands were selected at the population level ($\hat{w}$ = 1.70). Deer selected for CRP habitat especially during the parturition period (15 May – 15 June; Grovenburg et al. 2010*b*), and used CRP throughout the summer for bedding and escape cover. Grovenburg et al. (2011) indicated that CRP grassland habitat was critical for white-tailed deer and that increased fawn survival was attributed to availability of this resource. Likewise, Gould and Jenkins (1993) determined that CRP grasslands provided critical undisturbed fawning habitat.

Kernohan et al. (1996) reported similar summer habitat use of white-tailed deer in east central South Dakota and found that deer on average used grasslands (30.7%), wetlands (16.7%) and standing corn (16.4%) most frequently. One notable difference was that deer in our study area did not utilize small grains as heavily compared to deer in east central South Dakota. Limited small grain fields (< 8%) were planted on the landscape in the Clark County area. Because vegetative vertical height rarely exceeded 1 m, we speculate limited use was attributed to the poor escape cover small grain fields provided and deer in the Clark County area selected resources of higher quality and quantity.

MANAGEMENT IMPLICATIONS

Our findings suggest that CRP grasslands, wetlands, and trees are critical resources for white-tailed deer in the agricultural landscapes of the Northern Great Plains. Because of the continued loss of CRP grassland habitat, which is being converted into agricultural row crops, continued drain tiling practices and the loss of fence lines and shelterbelts, conservative harvest strategies may be necessary in the future to maintain deer populations. The monetary value of commodity crops (i.e., corn and soybeans) has impacted the availability of suitable wildlife habitat. High commodity prices have increased rental rates and land values, forcing producers to maximize productivity of all land capable of producing crops. Continued aggressive farming practices in the Northern Great Plains will likely lead to changes in white-tailed deer behavior and survival.

LITERATURE CITED

Arthur, S. M., B. F. J. Manly, L. L. McDonald, and G. W. Garner. 1996. Assessing habitat selection when availability changes. Ecology 77:215-227.

Beier, P., and D. R. McCullough. 1990. Factors influencing white-tailed deer activity patterns and habitat use. Wildlife Monographs 109:1-51.

Beringer, J., L. P. Hansen, W. Wilding, J. Fischer, and S. L. Sheriff. 1996. Factors affecting capture myopathy in white-tailed deer. Journal of Wildlife Management 60:373-380.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, B. S. Haroldson, and R. G. Osborn. 2005. Movement of female white-tailed deer: effects of climate and intensive row-crop agriculture. Journal of Wildlife Management 69:1099-1111.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, J. D. Erb, and B. S. Haroldson. 2002. A vehicle-mounted radiotelemetry antenna system design. Wildlife Society Bulletin 30:258-262.

Bryce, S., J.M. Omernik, D.E. Pater, M.Ulmer, J. Schaar, J.Freeouf, R.Johnson, P. Kuck, and S.H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. Jamestown, ND: Northern Prairie Wildlife Research Center Online.

Burris, B. M. 2005. Seasonal movements of white-tailed deer in eastern South Dakota and southwestern Minnesota relative to traditional ranges and management unit boundaries. M. S. Thesis, South Dakota State University, Brookings, USA.

Calenge, C. 2006. The package “adehabitat” for R software: A tool for the analysis of space and habitat use by animals. Ecological Modelling 197:516-519.

Calenge, C., and A. B. Dufour. 2006. Eigenanalysis of selection ratios from animal radio-tracking data. Ecology 87:2349-2355.

Clover, M. R. 1956. Single gate deer trap. California Fish and Game 42:199-201.

Cox, R. R., Jr., J. D. Scalf, B. E. Jamison, and R. S. Lutz. 2002. Using an electronic compass to determine telemetry azimuths. Wildlife Society Bulletin 30:1039-1043.

DelGuidice, G. D., B. A. Mangipane, B. A. Sampson, and C. O. Kochanny. 2001. Chemical immobilization, body temperature, and post-release mortality of white-tailed deer captured by Clover trap and net-gun. Wildlife Society Bulletin 29:1147-1157.

DePerno, C. S., J. A. Jenks, and S. L. Griffin. 2003. Multidimensional cover characteristics: is variation in habitat selection related to white-tailed deer sexual segregation. Journal of Mammalogy 84:1316-1329.

Dusek, G. L., R. J. Mackie, J. D. Herriges, Jr., and B. B. Compton. 1989. Population ecology of white-tailed deer along the lower Yellowstone River. Wildlife Monographs 104:1-68.

Dusek, G. L., A. K. Wood, and R. J. Mackie. 1988. Habitat use by white-tailed deer in prairie-agricultural habitat in Montana. The Prairie Naturalist 20:135-142.

Fagen, R. 1988. Population effects of habitat change: a quantitative assessment. Journal of Wildlfie Management. 52:41-46.

Gould, J. H., and K. J. Jenkins. 1993. Seasonal use of Conservation Reserve Program lands by white-tailed deer in east-central South Dakota. Wildlife Society Bulletin 21:250-255.

Grovenburg, T. W. 2007. Movement patterns of white-tailed deer in east central South Dakota relative to winter ranges and management unit boundaries. M. S. Thesis, South Dakota State University, Brookings, USA.

Grovenburg, T. W., C. C. Swanson, C. N. Jacques, R. W. Klaver, T. J. Brinkman, B. B. Burris, C. S. DePerno, and J. A. Jenks. 2011. Survival of white-tailed deer neonates in Minnesota and South Dakota. Journal of Wildlife Management 75:213-220.

Grovenburg, T. W., C. N. Jacques, C. C. Swanson, R. W. Klaver, and J. A. Jenks. 2010*a*. Use of late season standing corn by female white-tailed deer in the northern Great Plains during a mild winter. The Prairie Naturalist 42(1/2):8-18.

Grovenburg, T. W., C. N. Jacques, R. W. Klaver, and J. A. Jenks. 2010*b*. Bed site selection by neonate white-tailed deer in grassland habitats on the Northern Great Plains. Journal of Wildlife Management 74:1250-1256.

Habeck, J. R. 1960. Winter deer activity in the white cedar swamps of northern Wisconsin. Ecology 41:327-333.

Hobbs, N. T., and T. A. Hanley. 1990. Habitat evaluation: Do use/availability data reflect carrying capacity? Journal of Wildlife Management 54:515-522.

Irwin, L. L. 1974. Relationships between deer and moose on a burn in northeastern Minnesota. Thesis, University of Idaho, Moscow, USA.

Johnson, J. R., and G. E. Larson. 1999. Grassland plants of South Dakota and the Northern Great Plains. South Dakota State University College of Agriculture & Biological Sciences, South Dakota Agriculture Experiment Station, Brookings, USA.

Johnson, R. R., K. F. Higgins, M. L. Kjellsen, and C. R. Elliott. 1997. Eastern South Dakota wetlands. Brookings: South Dakota State University. Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov /resource/wetlands/eastwet/index.htm>. Accessed 9 July 2011.

Kernohan, B. J. 1994. Winter/spring population characteristics of white-tailed deer in an agricultural/wetland complex in northeastern South Dakota. Thesis, South Dakota State University, Brookings, USA.

Kernohan, B. J., J. A. Jenks, D. E. Naugle, and J. J. Millspaugh. 1996. Estimating 24-h habitat use patterns of white-tailed deer from diurnal use. Journal of Environmental Management 48:299-303.

Kennedy, J. F. 1992. Habitat selection by female white-tailed deer in the northern Black Hills, South Dakota and Wyoming. Thesis, South Dakota State University, Brookings. USA.

Klaver, R. W., J. A. Jenks, C. S. DePerno, and S. L. Griffin. 2008. Associating seasonal range characteristics with survival of female white-tailed deer. Journal of Wildlife Management 72:343-353.

Kohn, B. E., and J. J. Mooty. 1971. Summer habitat of white-tailed deer in north-central Minnesota. Journal of Wildlife Management 35:476-487.

Kramlich, T. J. 1985. Evaluation of seasonal use by white-tailed deer in eastern South Dakota. Thesis, South Dakota State University, Brookings, USA.

Larson, T. J., O. J. Rongstad, and F. W. Terbilcox. 1978. Movement and habitat use of white-tailed deer in south-central Wisconsin. Journal of Wildlife Management 42:113-117.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Second edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Martinka, C. J. 1968. Habitat relationships of white-tailed and mule deer in northern Montana. Journal of Wildlife Management 32:558-565.

Meyer, C. B., and W. Thuiller. 2006. Accuracy of resource selection functions across spatial scales. Diversity and Distributions 12:288-297.

Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. Journal of Wildlife Management 42:715-738.

Mooty, J. J., P. D. Karns, and T. K. Fuller. 1987. Habitat use and seasonal range size of white-tailed deer in northcentral Minnesota. Journal of Wildlife Management 51:644-648.

Mundinger, J. G. 1980. Population ecology and habitat relationships of white-tailed deer in coniferous forest habitat of northwestern Montana. Pages 8-92 *in* Montana deer studies. Montana Department of Fish, Wildlife, and Parks, Job Program Report, Helena, USA.

Murphy, R. K., N. F. Payne, and R. K. Anderson. 1985. White-tailed deer use of an irrigated agricultural-grassland complex in central Wisconsin. Journal of Wildlife Management 49:125-128.

Mysterud, A., and R. A. Ims. 1998. Functional responses in habitat use: availability influences relative use in trade-off situations. Ecology 79:1435-1441.

Nams, V. O. 2006. Locate III User's Guide. Pacer Computer Software, Tatamagouche, Nova Scotia, Canada.

Nams, V. O. 1999. Effects of radiotelemetry error on sample size and bias when testing for habitat selection. Canadian Journal of Zoology 67:1631-1636.

National Climatic Data Center. 2011. Record of Climatological Observations. <http://www7.ncdc.noaa.gov/IPS/coop/coop.html>. Accessed 9 May 2011.

Nixon, C. M., L. P. Hansen, P. A. Brewer, and J. E. Chelsvig. 1991. Ecology of white-tailed deer in an intensively farmed region of Illinois. Wildlife Monographs 118:1-77.

Orians, G. H., and J. F. Wittenberger. 1991. Spatial and temporal scales in habitat selection. The American Naturalist 137:29-49.

Osko, T. J., M. N. Hiltz, R. J. Hudson, and S. M. Wasel. 2004. Moose habitat preferences in response to changing availability. Journal of Wildlife Management 68:576-584.

Otis, D. L. 1997. Analysis of habitat selection studies with multiple patches within cover types. Journal of Wildlife Management 61:1016-1022.

Ozoga, J. J., and L. W. Gysel. 1972. Response of white-tailed deer to winter weather. Journal of Wildlife Management 36:892-896.

Parker, K. L., C. T. Robbins, and T. A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management 48:474-488.

Pauley, G. R., J. M. Peek, and P. Zager. 1993. Predicting white-tailed deer habitat use in northern Idaho. Journal of Wildlife Management 57:904-913.

Petersen, L. E. 1984. Northern Plains. Pages 441-448 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Rodgers, A. R., and A. P. Carr. 1998. HRE: The home range extension for ArcView. Centre for Northern Forest Ecosystem Research, Ontario Ministry of Natural Resources, Ontario, Canada

Rosenberry, J. L., and A. Woolf. 1998. Habitat-population density relationships for white-tailed deer in Illinois. Wildlife Society Bulletin 26:252-258.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739-747.

Severinghaus, C. A. 1949. Tooth development and wear as criteria of age in white-tailed deer. Journal of Wildlife Management 13:195-216.

Severinghaus, C. A. and E. L. Cheatum. 1956. Life and times of the white-tailed deer. Pages 57-186 *in* W. P. Taylor, editor. The Deer of North America. Stackpole Books. Harrisburg, Pennsylvania, USA.

Singer, F. J. 1979. Habitat partitioning and wildlife relationships of cervids in Glacier National Park, Montana. Journal of Wildlife Management 43:437-444.

Smith, V. J., J. A. Jenks, C. R. Berry, Jr., C. J. Kopplin, and D. M. Fecske. 2002. The South Dakota Gap Analysis Project. Final Report. Research Work Order No. 65. Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, S.D, USA.

South Dakota Department of Game, Fish and Parks. 2010. 2009 Big game harvest projections. South Dakota Game Report No 2011-05. Division of Wildlife, South Dakota Department of Game, Fish and Parks, Pierre, USA.

South Dakota Office of Climatology. 2011. South Dakota climate and weather. <http://climate.sdstate.edu>. Accessed 2 May 2011.

Sparrowe, R. D., and P. F. Springer. 1970. Seasonal activity patterns of white-tailed deer in eastern South Dakota. Journal of Wildlife Management 34:420-431.

Swenson, J. E., S. J. Knapp, and H. J. Wentland. 1983. Winter distribution and habitat use by mule deer and white-tailed deer in southeastern Montana. The Prairie Naturalist 15:97-112.

United States Department of Agriculture. 2009. National Agricultural Imagery Program (NAIP). Farm Service Agency. <http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=nai>. Accessed 8 September 2009.

U.S. Geological Survey, Gap Analysis Program (GAP). 2010. National Land Cover, version 1. <http://gapanalysis.usgs.gov/data/land.cover.data>. Accessed 23 May 2011.

Verme, L. J. 1965. Swamp conifer deeryards in northern Michigan: their ecology and management. Journal of Forestry 63:523-529.

Wetzel, J. F., J. F. Wambaugh, and J. M. Peek. 1975. Appraisal of white-tailed deer winter habitats in northeastern Minnesota. Journal of Wildlife Management 39:59-66.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, California, USA.

Zwank, P. J., R. D. Sparrowe, W. R. Porath, and O. Torgerson. 1979. Utilization of threatened bottomland habitats by white-tailed deer. Wildlife Society Bulletin 7:226-232.

Table 4-1. Resource availability encompassing the MCP for female white-tailed deer at the population level for four seasons in eastern South Dakota.

	Winter 2009	Summer 2009	Winter 2010	Summer 2010
Habitat	Availability (%)	Availability (%)	Availability (%)	Availability (%)
Cut Corn	17.7	0.3	16.7	0
CRP	20.8	13.5	18.1	10.8
Bean Stubble	12.8	0	11	0
Trees	3.4	2.9	3.6	2.7
Wetland	21.5	21.7	24.9	25.2
Pasture	8.4	8.3	9.1	6
Wheat Stubble	6.3	0	4,7	0
Short Grass	2.1	1.4	1	2.06
Rye	1.3	0.4	0.8	0
Standing Corn	0.7	18.4	1	16.8
Tall Grass	1.2	0.6	1.1	1.4
Alfalfa	0.4	1.6	0.8	1.9
Development	1.7	2.7	2.5	3
Plowed field	2	0	4.7	0
Sorghum	0.2	0	0	0
Wheat	0	7.1	0	7.6
Standing Beans	0	21	0	22.6

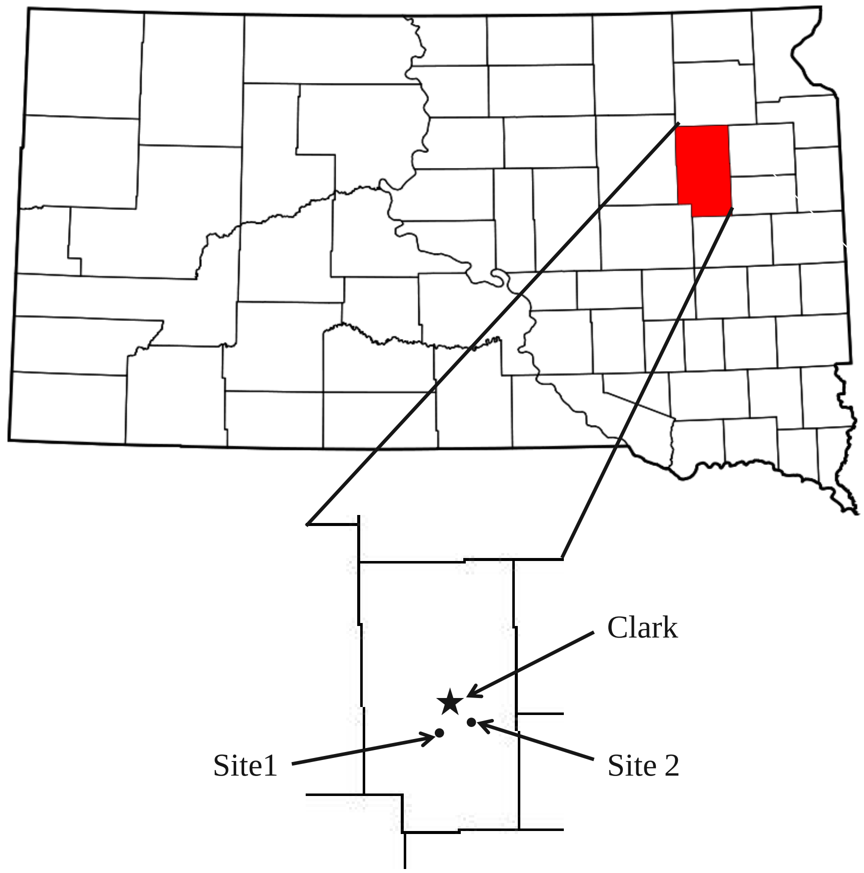


Figure 4-1. Clark County study area for white-tailed deer in Clark County, South Dakota, 2009-2011. Two capture sites for white-tailed deer are illustrated.

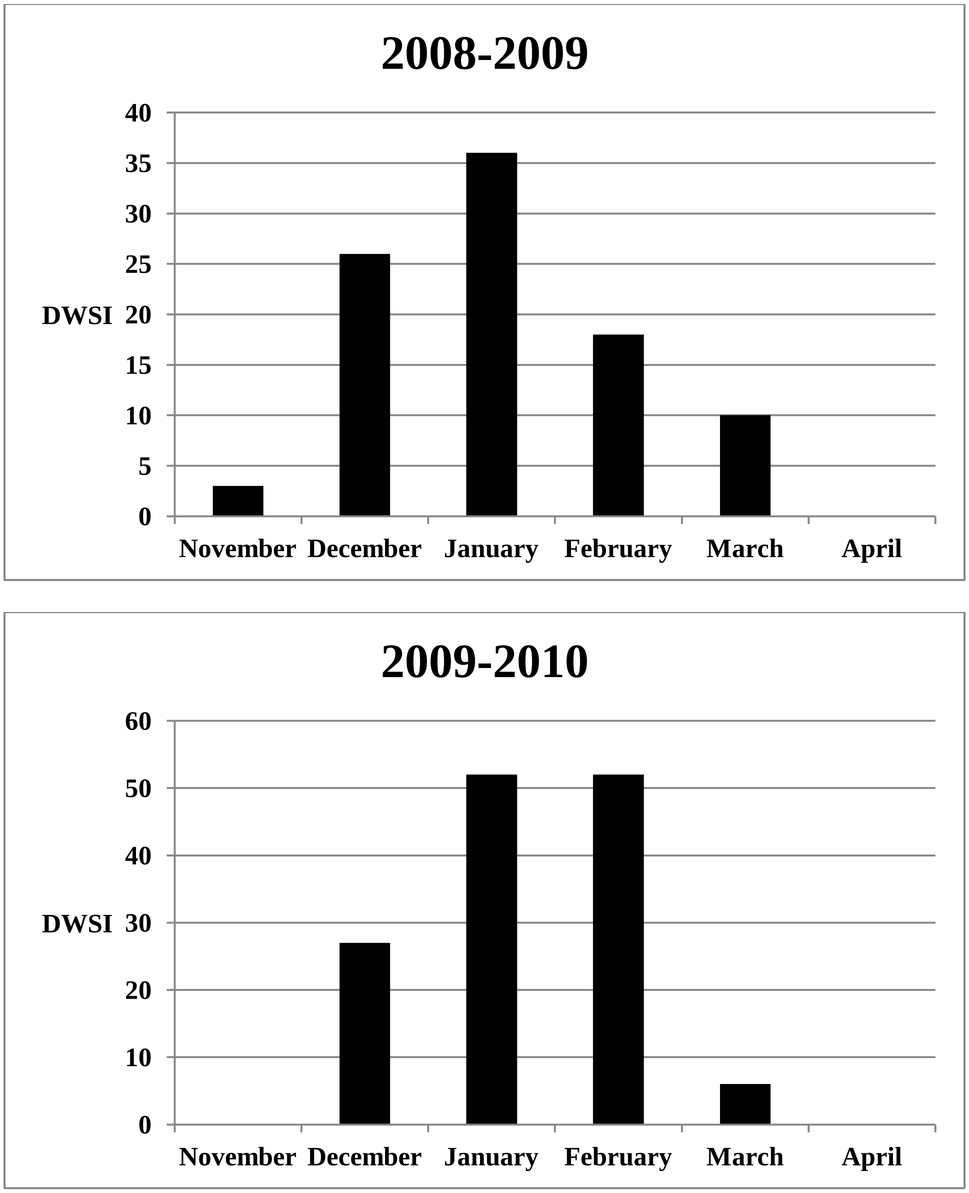


Figure 4-2. Monthly winter severity indices (DWSI) for white-tailed deer in Clark County, South Dakota. We assigned one point for each day mean temperature was ≤ -7 ^{o} C and an additional point for each day snow depth was ≥ 35.0 cm; National Climatic Center of Climatology 2011.

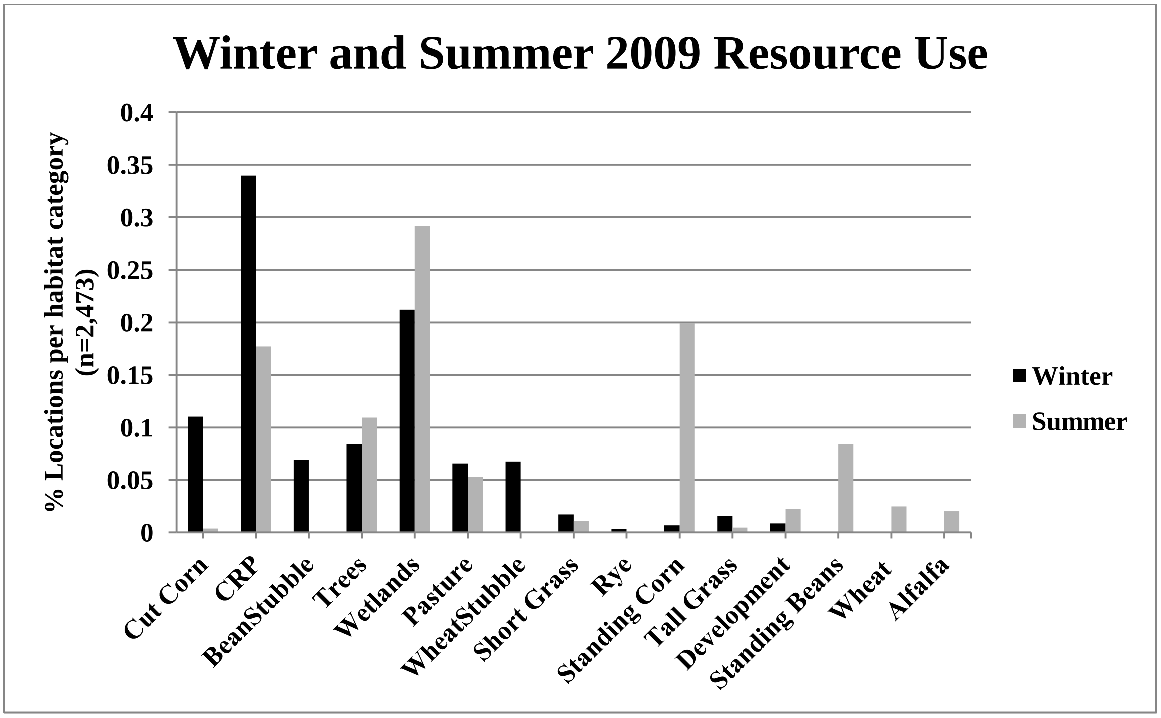


Figure 4-3. Percent difference of habitat types used by 25 adult female white-tailed deer in the winter and summer of 2009 in Clark County, South Dakota.

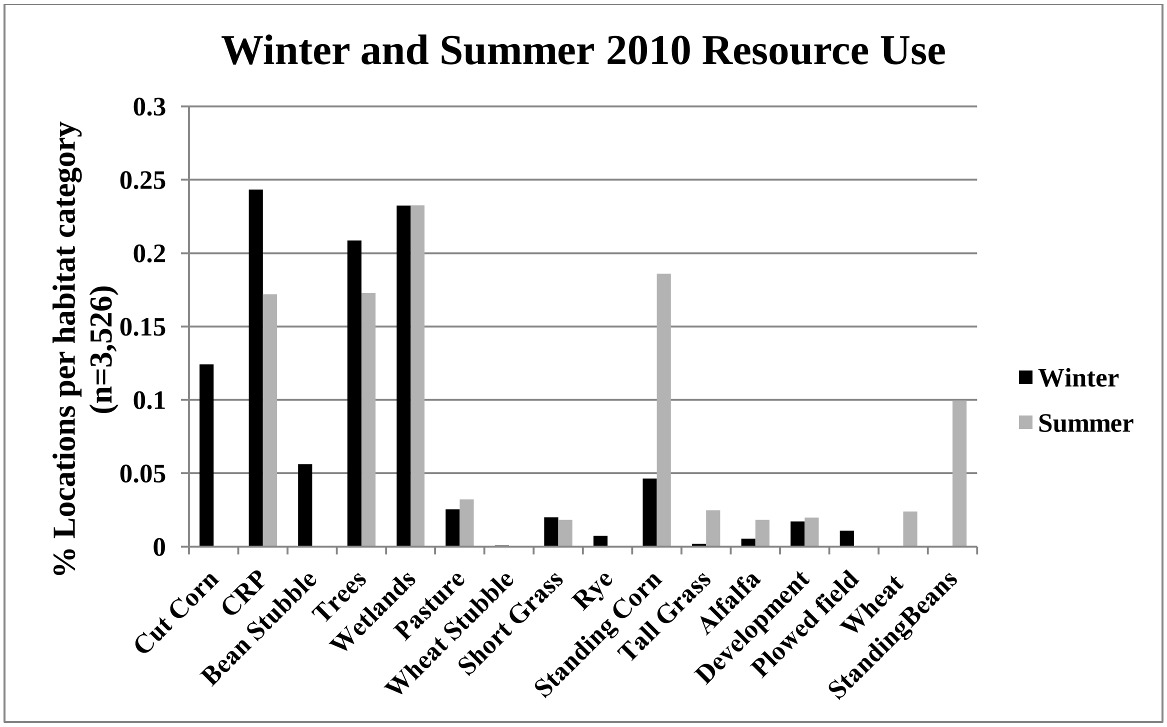
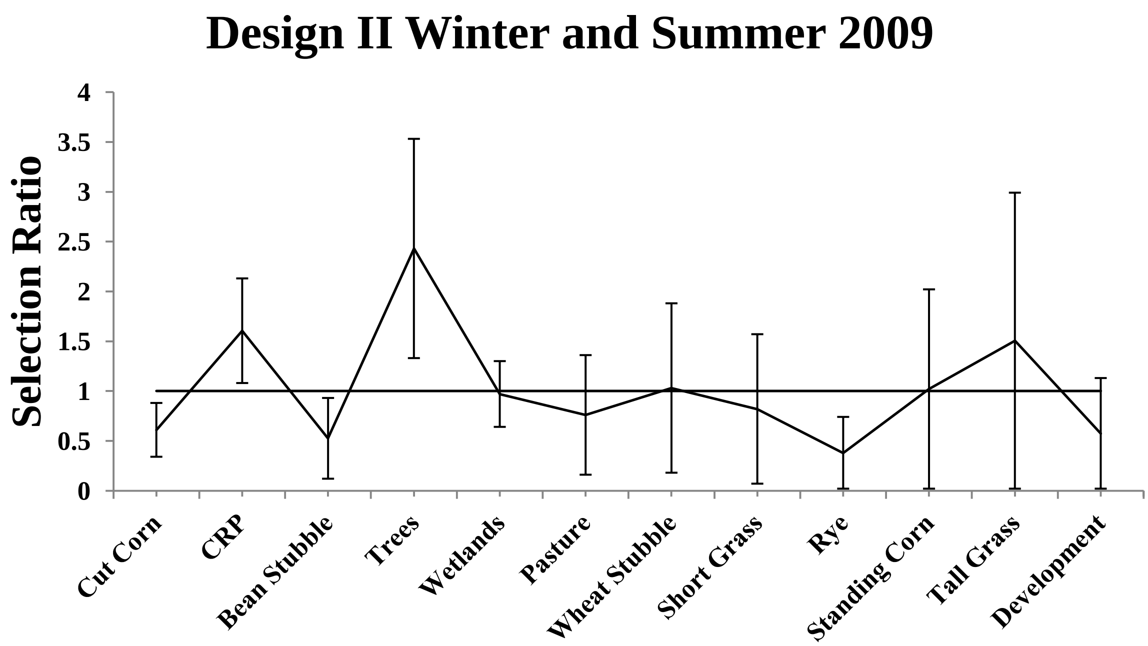


Figure 4-4. Percent difference of habitat types used by 36 adult female white-tailed deer in the winter and summer of 2010 in Clark County, South Dakota.

A.



B.

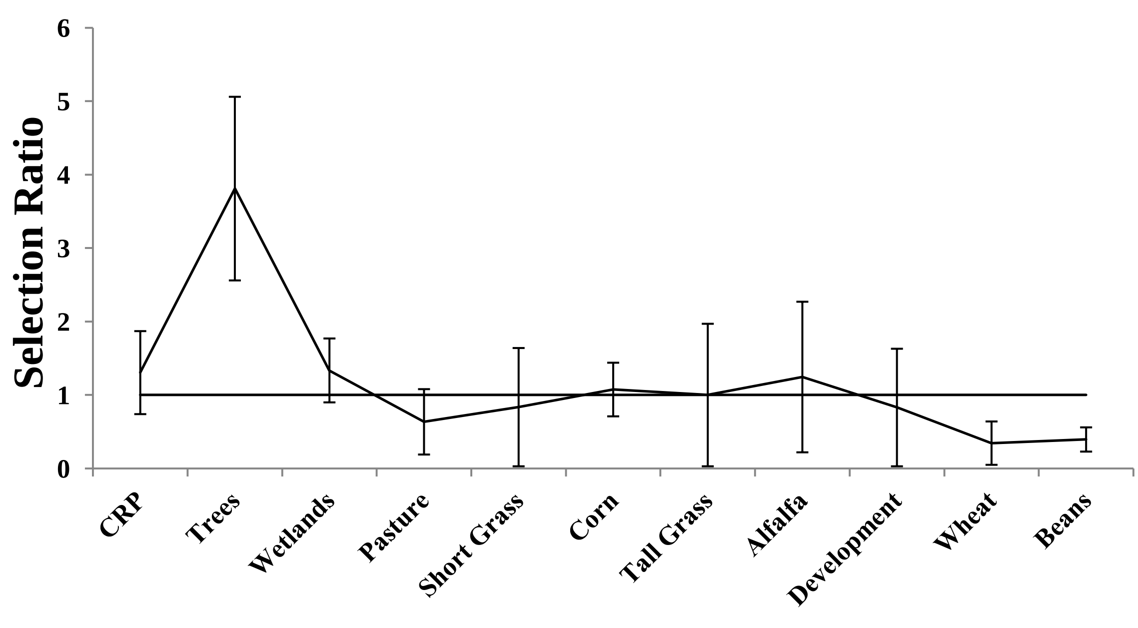
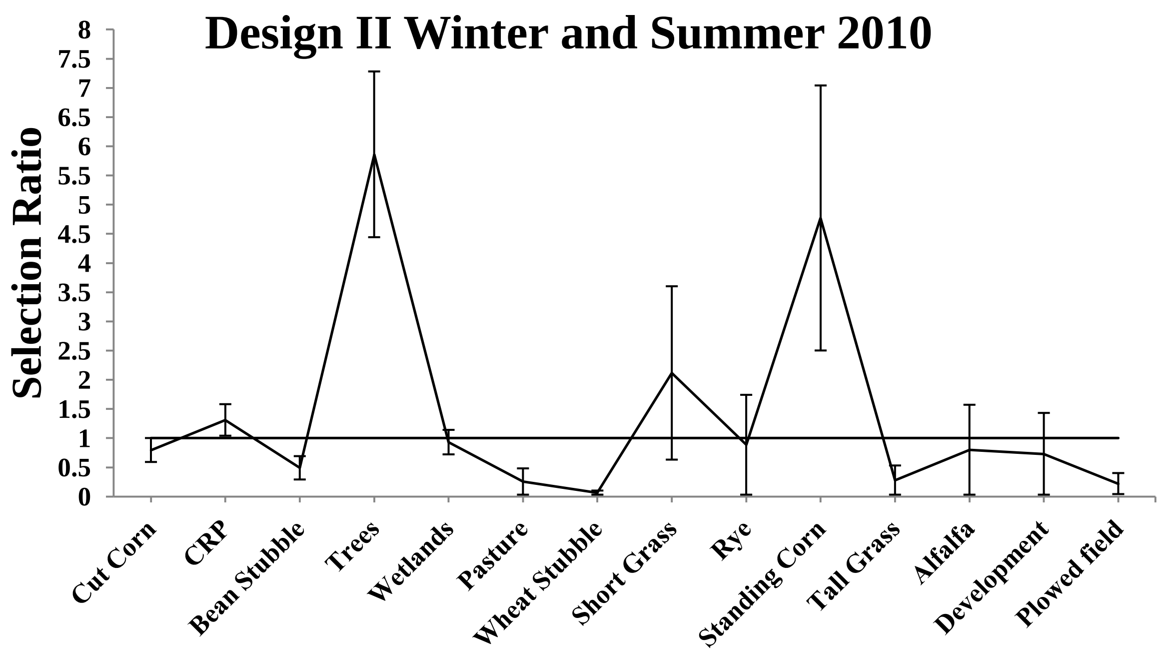


Figure 4-5. A) Resource selection ratios during winter 2009 B) Resource selection ratios during summer 2009; using design II (Manly et al. 2002) for 25 female white-tailed deer in Clark County, South Dakota.

A.



B.

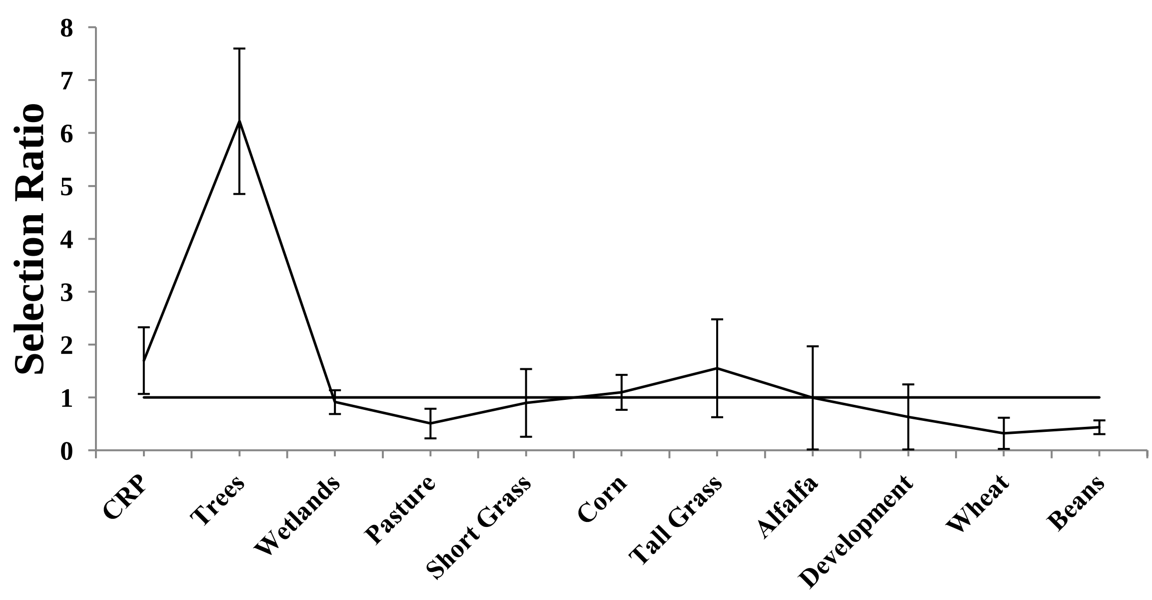
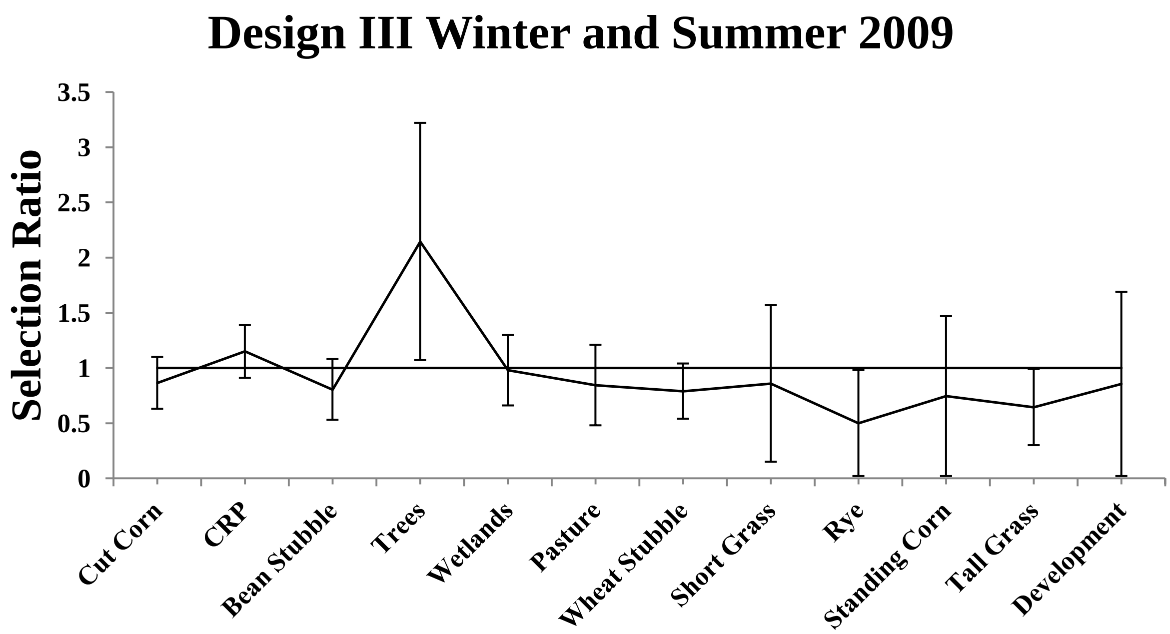


Figure 4-6. A) Resource selection ratios during winter 2010 B) Resource selection ratios during summer 2010; using design II (Manly et al. 2002) for 36 female white-tailed deer in Clark County, South Dakota.

A.



B.

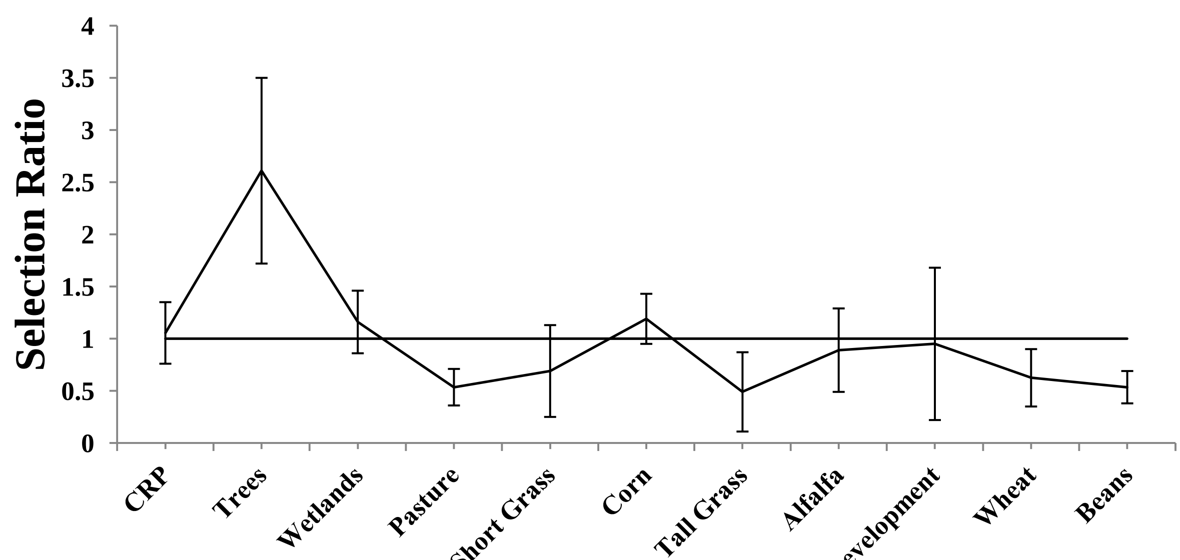
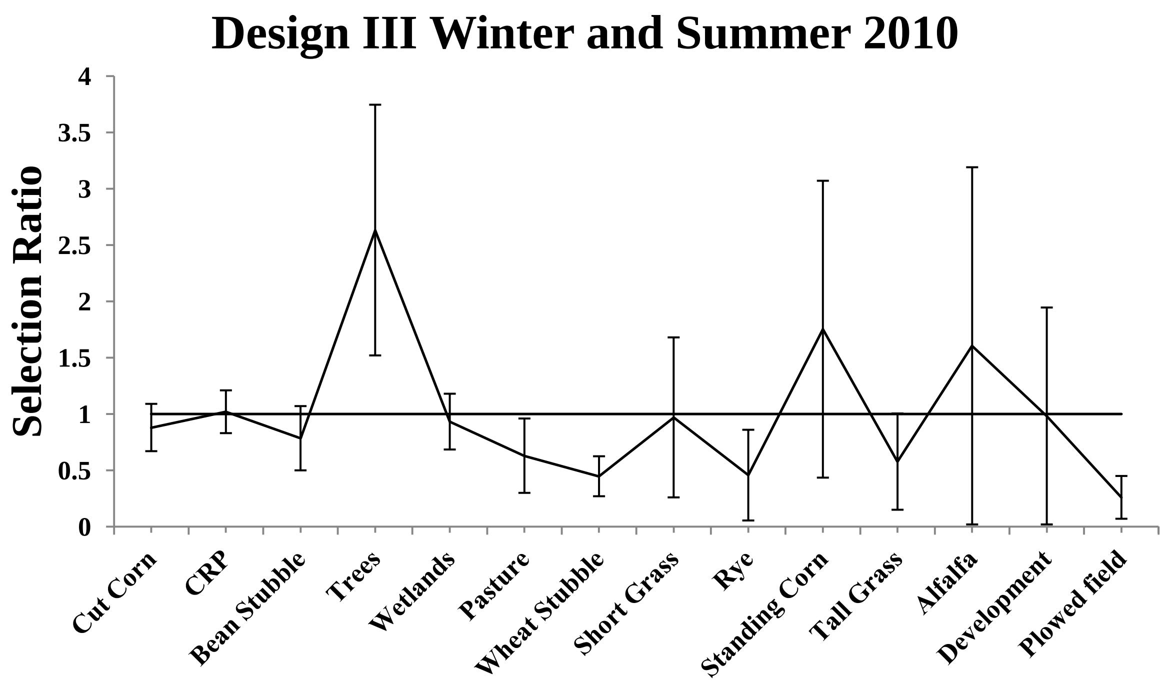


Figure 4-7. A) Resource selection ratios during winter 2009 B) Resource selection ratios during summer 2009; using design III (Manly et al. 2002) for 25 female white-tailed deer in Clark County, South Dakota.

A.



B.

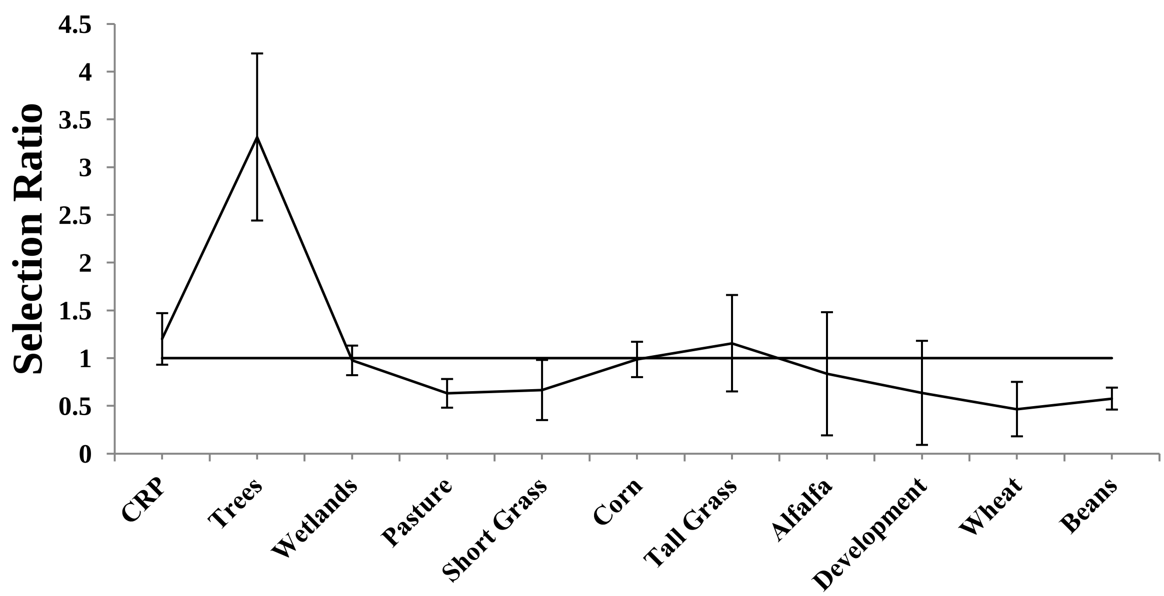


Figure 4-8. A) Resource selection ratios during winter 2010 B) Resource selection ratios during summer 2010; using design III (Manly et al. 2002) for 36 female white-tailed deer in Clark County, South Dakota.

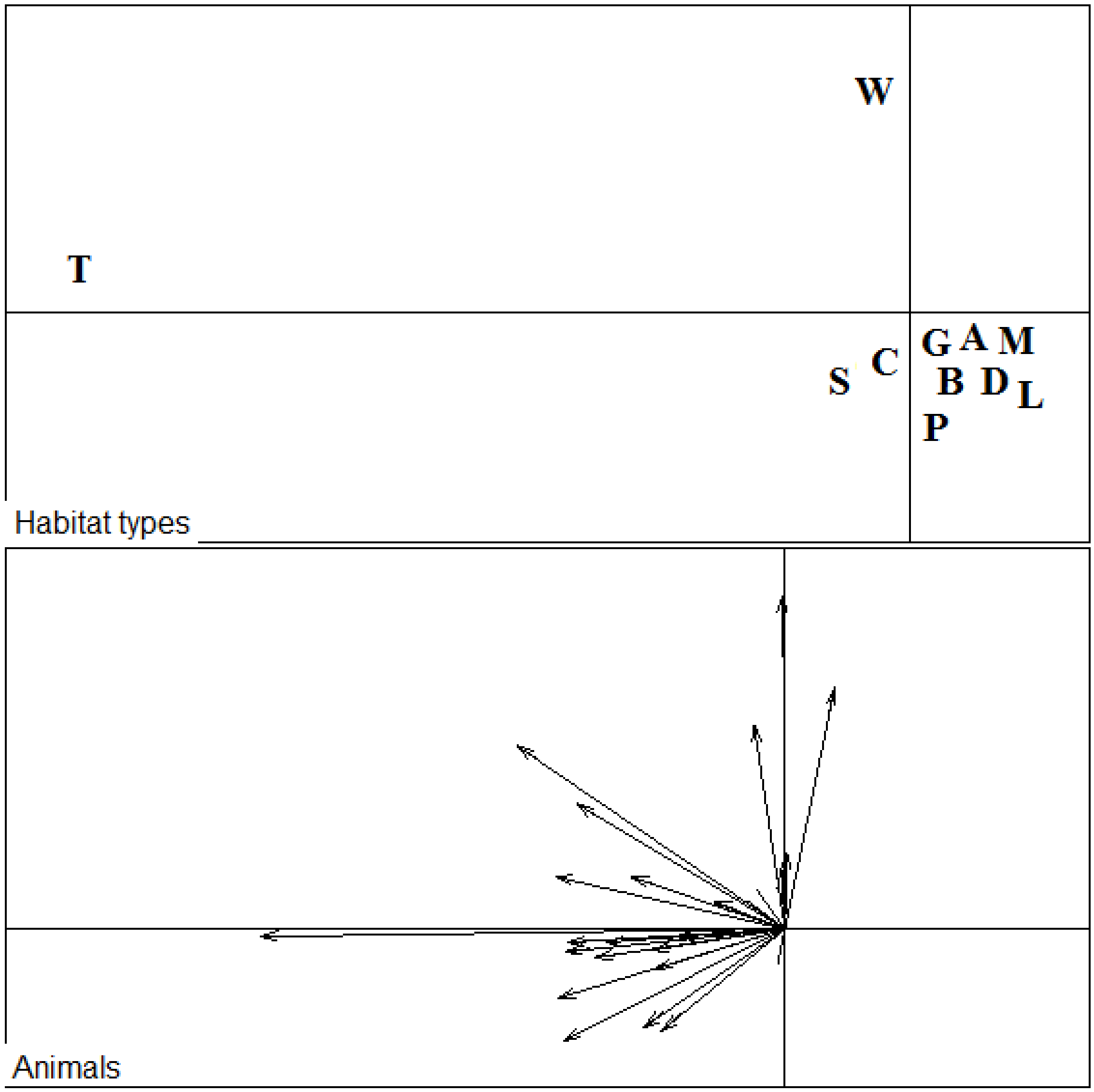


Figure 4-9. Results of the eigenanalysis (Calenge and Dufour 2006) of home range level (design III; Manly et al. 2002) selection ratios by 25 adult female white-tailed deer (*Odocoileus virginianus)* on eleven habitat variables during summer 2009 in eastern South Dakota, USA. Vectors represent individual adult females. M= tall grass, B = soybeans, T- trees, W= wetland, S= standing corn, C = CRP, G= short grass, L = alfalfa, A = wheat, P = pasture, D = development/roads.

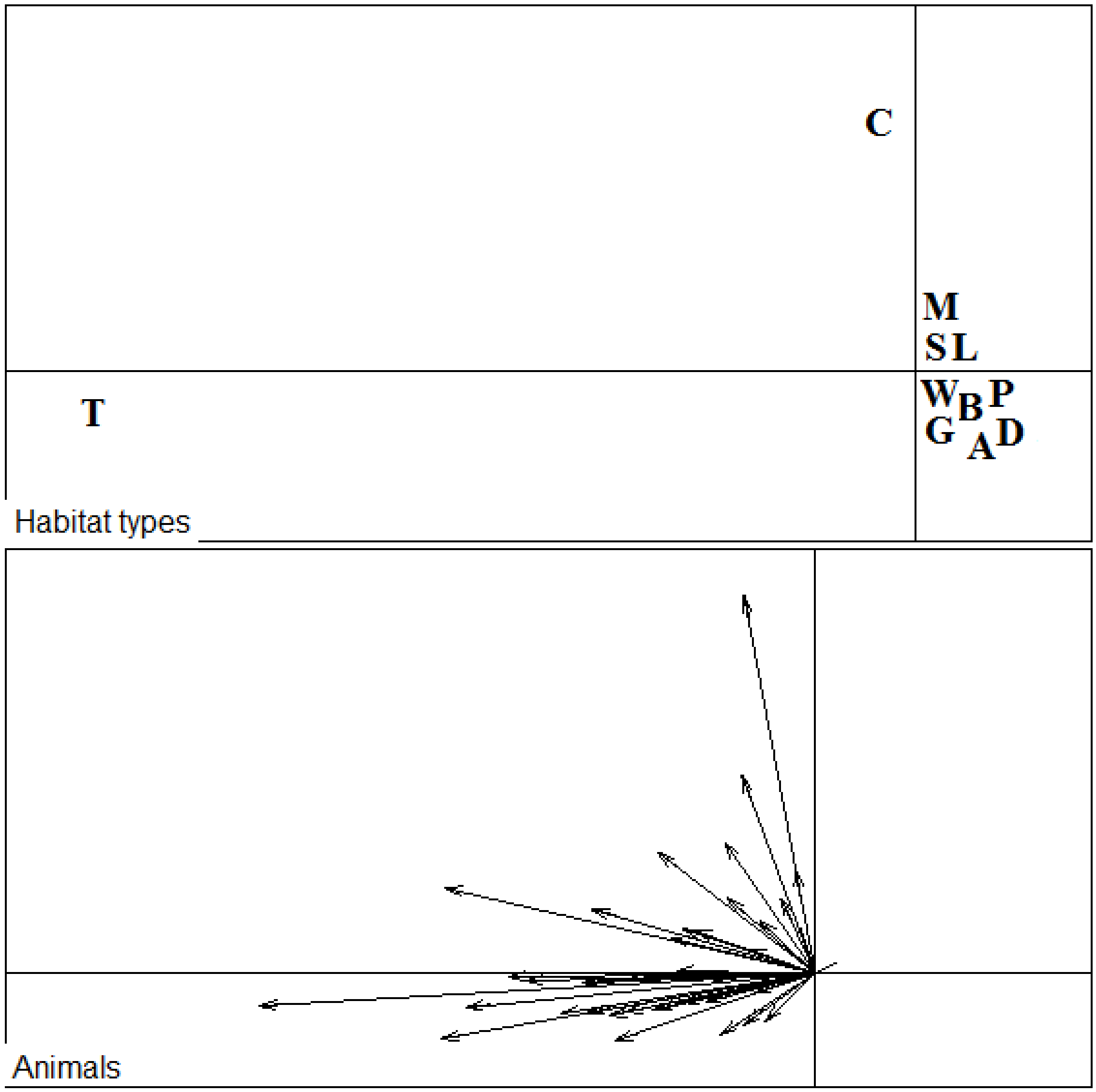


Figure 4-10. Results of the eigenanalysis (Calenge and Dufour 2006) of home range level (design III; Manly et al. 2002) selection ratios by 36 adult female white-tailed deer (*Odocoileus virginianus)* on eleven habitat variables during summer 2010 in eastern South Dakota, USA. Vectors represent individual adult females. M= tall grass, B = soybeans, T- trees, W= wetland, S= standing corn, C = CRP, G= short grass, L = alfalfa, A = wheat, P = pasture, D = development/roads.

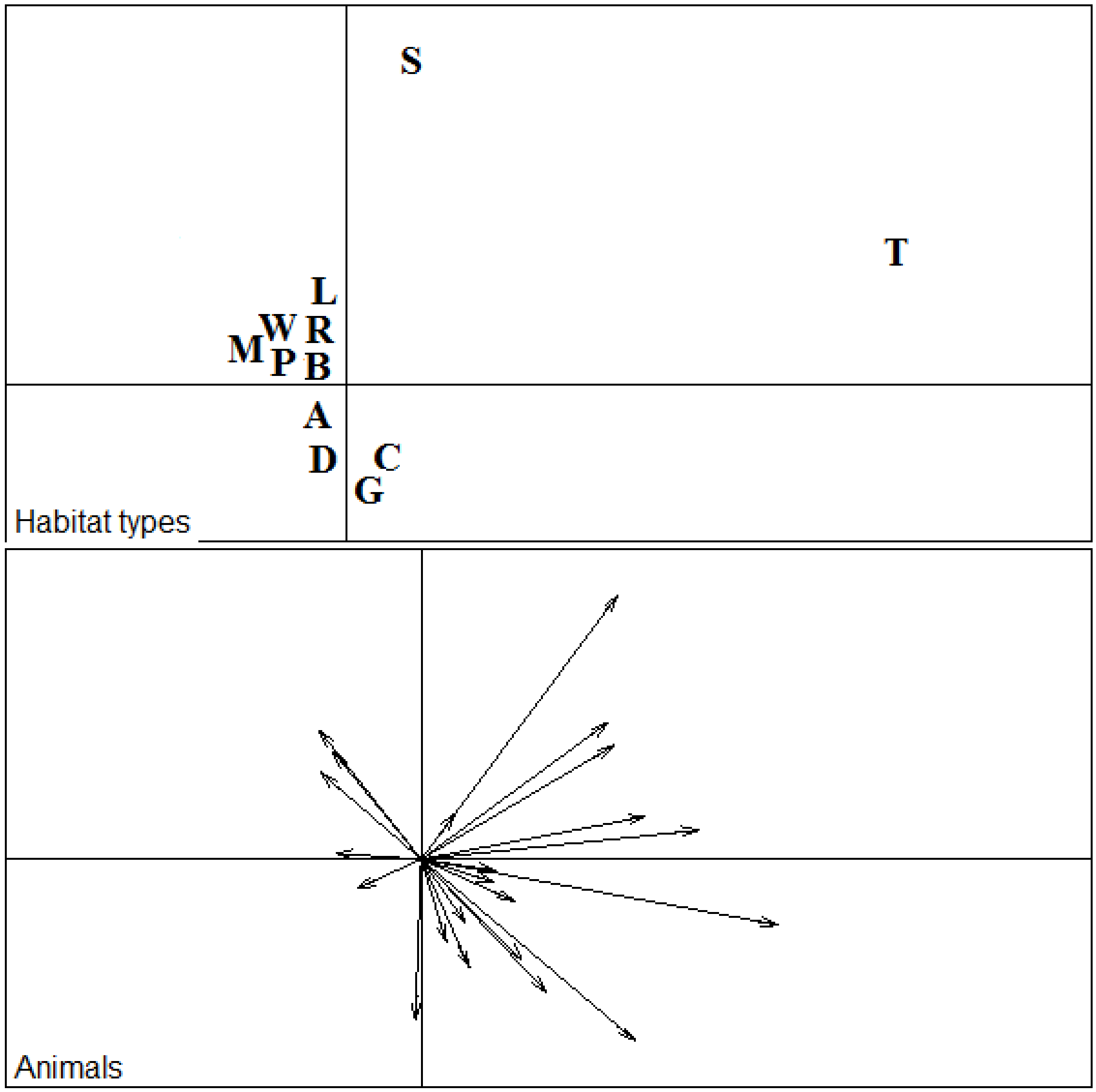


Figure 4-11. Results of the eigenanalysis (Calenge and Dufour 2006) of home range level (design III; Manly et al. 2002) selection ratios by 25 adult female white-tailed deer (*Odocoileus virginianus)* on twelve habitat variables during winter 2009 in eastern South Dakota, USA. Vectors represent individual adult females. M= tall grass, B = soybean stubble, T- trees, W= wetland, S= standing corn, C = CRP, G= short grass, L = cut corn, A = wheat stubble, P = pasture, D = development/roads, R = rye.

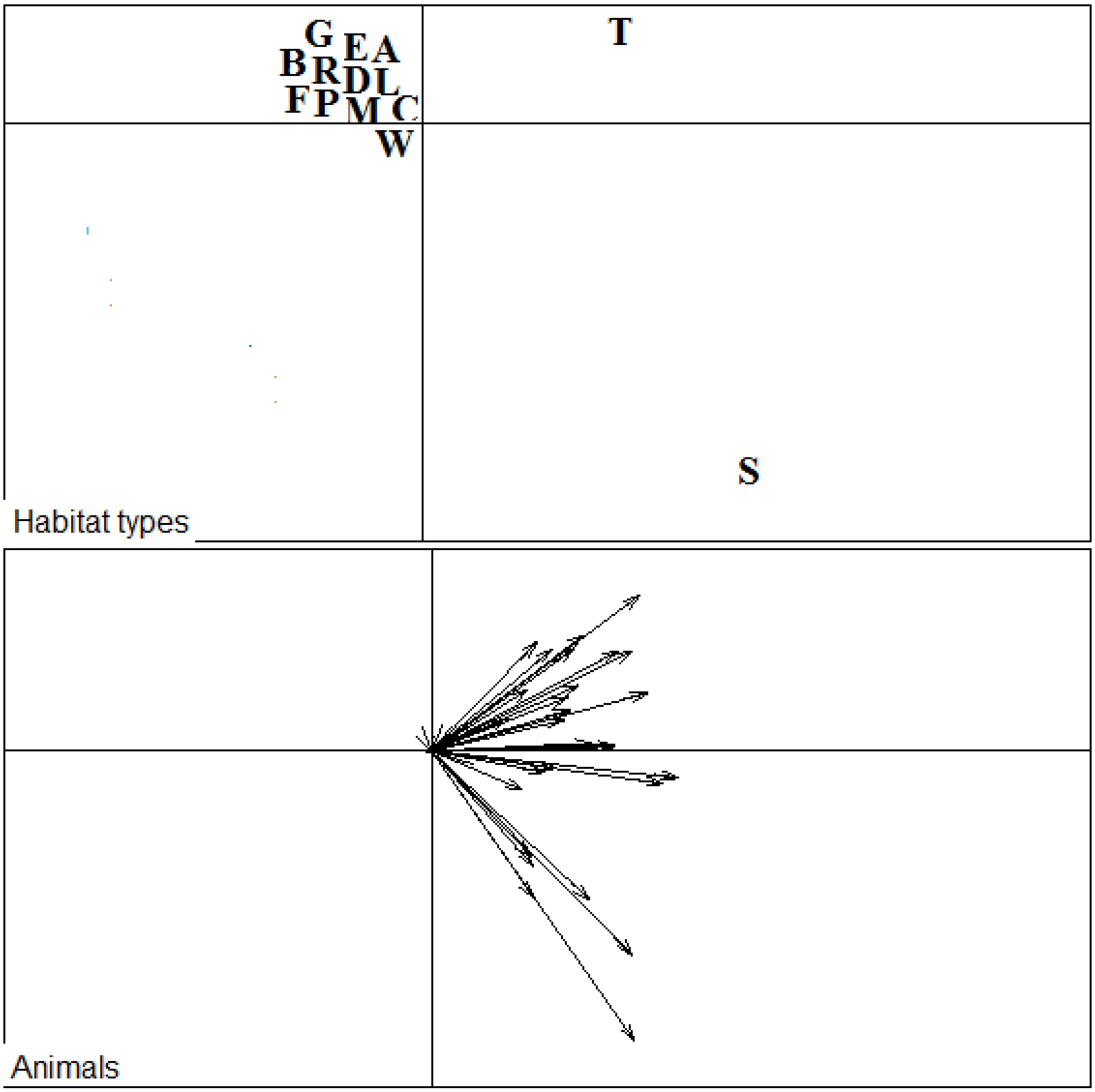


Figure 4-12. Results of the eigenanalysis (Calenge and Dufour 2006) of home range level (design III; Manly et al. 2002) selection ratios by 36 adult female white-tailed deer (*Odocoileus virginianus)* on fourteen habitat variables during winter 2010 in eastern South Dakota, USA. Vectors represent individual adult females. M= tall grass, B = soybean stubble, T- trees, W= wetland, S= standing corn, C = CRP, G= short grass, L = cut corn, E = alfalfa, F = plowed field, A = wheat stubble, P = pasture, D = development/roads, R = rye.

CHAPTER 5: SIGHTABILITY OF WHITE-TAILED DEER IN EASTERN SOUTH DAKOTA

ABSTRACT Few techniques have proved successful at providing reasonable estimates of white-tailed deer (*Odocoileus virginianus*) abundance primarily in regions characterized as forested but also in those dominated by prairie, such as South Dakota. Primary objectives of this study were to develop spring and winter sightability models for aerial surveying of deer. From February 2009 – February 2010, 43 adult female white-tailed deer and 5 adult male white-tailed deer were monitored and used to develop a sightability model for estimating density of deer. In spring 2009 and 2010, a total of seven sightability flights was conducted in late April and early May when potential color differences between sun-bleached deer and spring green-up of vegetation were present. In winter 2010 and 2011, a total of 8 flights was conducted in January and February when 100% snow cover was present and deer were in large herds. Variables for which data were collected during flights included: group size, activity, habitat, time of day, and canopy cover. Deer were sighted in the winter at a rate of 84.4% (146/173) and spring sightability rate was 54.6% (88/161). Logistic regression analysis indicated that visibility was significantly influenced by group size and canopy cover for both models. The winter model estimated deer sightability as $\mu = 3.064 + 0.044$ (group size) – 1.13 (canopy cover) and the spring model estimated deer sightability as $\mu = 2.297 + 0.252$ (group size) – 1.10 (canopy cover). These models will assist managers in estimating population size of white-tailed deer in agricultural dominated landscapes throughout eastern South Dakota.

INTRODUCTION

Accurate and precise population estimates are required for effective management of ungulate populations. Estimates of animal abundance allow documentation of population trends and rates of change and provide the basis for setting harvest limits (Miller et al. 1997). Aerial surveys often are used to quantify population size of large mammal species; however, few surveys accurately count all animals, due mainly to visibility biases (Caughley 1977). Caughley (1974, 1977) defined visibility bias "as the failure to observe all animals" and explained that it is the general cause of inaccuracy in aerial surveys. In addition, Caughley (1977) reported that aerial surveys failed to detect 12-71% of animals known to be present in a study area with flat and open terrain. Total counts of ungulate populations are generally not reliable and numerous aerial surveys have documented biases associated with underestimates of population size (Caughley 1974, LeResche and Rausch 1974, Floyd et al. 1979, DeYoung 1985). One approach used to correct for visibility bias of ungulates populations is development of sightability models (Samuel et al. 1987).

Sightability models estimate population size by calculating the detection probability of individual groups and correcting for groups missed during surveys by documenting factors affecting animal detection (Samuel et al. 1987). Factors affecting sightability include type of aircraft, speed, altitude, strip width, group size, group activity (i.e., bedded, standing, moving), observer experience, vegetative cover, canopy cover, topography, and snow cover (Caughley 1974, Samuel et al. 1987, Otten et al. 1993, Bodie et al. 1995, Anderson et al. 1998, Cogan and Diefenbach 1998, Allen 2005, Jacques

2006, Krueger et al. 2007, Mcintosh et al. 2009, Rice et al. 2009, Walsh et al. 2009, Jarding 2010). Detection probabilities for sightability models are not constant and individual groups do not have equal and independent probabilities of being detected (Pollock and Kendall 1987, Anderson 1994). Logistic regression models are commonly used to determine predictor variables based on various group-specific and environmental covariates (Samuel et al. 1987, Walsh et al. 2009).

Sightability models are developed by flying over groups of animals containing marked individuals and by recording covariates for individual groups both observed and undetected by observers (Samuel et al. 1987). Marked individuals are needed for model development (Anderson 1994, Jarding 2010) whereas model applicability depends on the environment (i.e., snow condition, canopy cover, speed, altitude, vegetative cover, group size) of future surveys (White and Shenk 2001). Furthermore, the model cannot be used if future surveys do not reflect conditions that are similar to those experienced during model development. In addition, Steinhorst and Samuel (1989) noted that the application of sightability models during aerial surveys must meet several assumptions including: 1) the population is demographically and geographically closed, 2) observations of animal groups are independent, 3) groups are observed and counted only once, 4) the survey design for land units is specified, and 5) probability of observing a group is known or can be estimated.

Sightability models have been widely used to estimate population size on a wide array of large ungulate species including elk (*Cervus elaphus*; Samual et al. 1987), bighorn sheep (*Ovis canadensis*; Bodie et al. 1995), moose (*Alces alces*; Anderson and

Lindsey 1996), mule deer (*Odocoileus hemionus*; Ackerman 1998), white-tailed deer (*Odocoileus virginianus*; Grassel 2000), pronghorn (*Antilocapra americana*; Jacques 2006) oryx (*Oryx gazella gazelle*; Krueger et al. 2007) and mountain goats (*Oreamnos americanus*; Rice et al. 2009). Although a white-tailed deer sightability model was developed in the Missouri River Breaks Region of central South Dakota; vegetative characteristics, topography and survey conditions are considerably different compared to the agricultural landscapes that typify eastern South Dakota and where a regression-based sightability model has not been developed. Thus, our objectives were to construct a logistic regression model to estimate white-tailed deer sightability and evaluate factors contributing to visibility bias during spring and winter survey flights in the Prairie Pothole Region of eastern South Dakota.

STUDY AREA

We conducted sightability trials in Clark County, South Dakota (Figure 1), within a 1,294 km^2 study area. Mean annual (30-yr) precipitation was 56.2 cm and mean (30-yr) monthly temperature ranged from -11.9^{o}C to 21.8^{o}C (South Dakota Office of Climatology 2011). Clark County is located in the level III ecoregion of the Northern Glaciated Plains (Bryce et al. 1998) and lies in the Prairie Pothole Region (Johnson et al. 1997). Soils of the area are composed of glacial till and topography was flat to gently rolling terrain intermixed with numerous semi-permanent, temporary, and seasonal wetlands that were formed by glacial actions (Bryce et al. 1998, Johnson et al. 1997). Within the 1,294 km^2 study area, cultivated crops, including corn (*Zea mays*), soybeans (*Glycine max*) and wheat (*Triticum aestivum*) made up 48% and pasture land 8% of the landscape. Wetlands comprised 23% and grasslands 15% of the landscape. Woodland plantings and shelterbelts and developed areas each covered 3% of the landscape (Smith et al. 2002).

Native warm and cool season grasslands that were enrolled in the Conservation Reserve Program (CRP) were comprised of, but not limited to, big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), western wheatgrass (*Elymus smithii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and smooth brome (*Bromus inermis*). Wetland vegetation was dominated by cattails (*Typha* spp.), sedges (*Carex* spp.), rushes (*Juncus* spp.), reed canarygrass (*Phalaris arundinacea*), prairie cordgrass (*Spartina pectinata*), and common reed (*Phragmites australis*). Woodlands and shelterbelts in this area were comprised primarily of American elm (*Ulmus americana*), green ash (*Fraxinus pennslyvanica*), eastern cottonwood (*Populus deltoides*), boxelder (*Acer negundo*) and eastern red ceder (*Juniperus virginiana*: Johnson and Larson 1999).

METHODS

Capture and Handling

From 22 January to 15 February 2009 and from 7 January to 25 February 2010 we captured white-tailed deer using modified Clover traps (Clover 1956) and helicopter net guns (DelGuidice et al. 2001). All captured deer were sexed and aged as fawn (~8-10 months), yearling (8 – 18 months) or adult (> 1.5 years) based on tooth replacement and incisor wear (Severinghaus 1949, Severinghaus and Cheatum 1956). We ear-tagged all animals with metal and plastic ear-tags (Hasco Tag Company, Dayton, KY, USA), and fitted adult females with brown or white VHF (Very High Frequency) radiocollars (Advanced Telemetry Systems, Inc., Isanti, MN) that were equipped with mortality sensors, which activated if the collar remained still for 8 hours. Concerns regarding animal welfare were addressed by checking traps daily at first light, manually restraining and blindfolding all captured individuals, and monitoring rectal temperatures as an index of stress (DelGiudice et al. 2001). All methods described in this research were approved by the Institutional Animal Care and Use Committee (IACUC, Approval No. 08-A028) at South Dakota State University.

Survey Methods

We conducted spring sightability flights from 20 April to 5 May 2009 and 8 to 14 April 2010. We flew survey flights during peak spring green up when potential color differences between sun-bleached deer and actively growing green vegetation were present. We conducted winter sightability trials between 16-28 February 2010 and 26 January – 4 February 2011 when 100% snow cover was present. Prior to flying sightability trials, we conducted a complete and thorough ground reconnaissance using a vehicle mounted “null-peak” antenna system (Brinkman et al. 2002) to determine where radio marked individuals were located to maximize sampling efforts and eliminate unnecessary flight time.

All flights were flown using a Cessna 172 fixed wing aircraft and standard assignments were given to observers. The navigator sat in the back seat diagonally across from the pilot and radio-located deer using (2) 4-element yagi antennas (Advanced Telemetry Systems, Inc., Isanti, MN) that were mounted to wing struts. The navigator also delineated transect boundaries and recorded data. Two primary observers were present in the plane; one was positioned next to the pilot while the other was positioned in the rear seat behind the pilot. The same two primary observers were used for all sightability trials throughout model development and their sole responsibility was to detect and count deer. One pilot was used for all flights. We flew parallel north to south or south to north transects spaced at 600-800 m intervals over the survey area where the radio-collared deer were located. We determined distances based on natural topographic features (roads and fence lines) that were identifiable from the air (Samuel et al. 1987, Ackerman 1988). The aircraft was flown at an altitude of 45-60 m above the ground at speeds ranging from 125-145 km/hr (Grassel 2000). Surveys began at sunrise or three hours before sunset and were completed within 2-3 hours.

When a white-tailed deer group defined as containing at least one radiocollared individual was observed, we interrupted the search pattern until all deer were counted and data recorded. We collected information on group size, vegetative type (i.e., habitat type), percent canopy cover, activity, and flight number. If a radiocollared individual was not observed during the survey the observers were notified after sampling efforts were completed for that individual and telemetry equipment was used to locate the missed group. Once located, the same variables were recorded; however, when the group could not be found or visually observed, that group was censored from the trial. We recorded multiple radiocollared deer in a group as one observation because we defined our sampling unit as the group not the individual (Samuel et al. 1987).

Activity of the group was recorded and categorized as 1 - moving, 2 - standing, or 3 - bedded for the first individual seen. Vegetation type (i.e., habitat type) for the winter and spring models were recorded and categorized as 1 - trees, 2- CRP grasslands, 3 - cattails (*Typha latifolia*), 4 - pasture, 5 - small grain/hay, 6 - standing corn, and 7 – harvested crops. The habitat type occupied by the majority of the group was recorded. Percent canopy cover was visually estimated around the site where the deer group was first seen and the values of 0- (0%), 1- (1-24%), 2- (25-49%), 3- (50-74%), or 4- (75-100%) were assigned to calculate detection probabilities. Because measuring vegetative cover is subjective and can vary significantly between observers (Anderson 1994), we used example diagrams/pictures from Unsworth et al. (1999) to minimize variability.

Sightability Analysis

We performed a stepwise logistic regression analysis using SYSTAT (SPSS Inc. 1999); with groups seen and missed as the response variable. Independent variables included group size, animal behavior, vegetative type (i.e., habitat), and percent canopy cover. Independent variables that were significant ($p \leq 0.05$) were used for model development. The detection probability equation used in the analysis for predicting sightability was:

$$p = \frac{e^u}{1 + e^u}$$

Where p is the probability of observing a group of deer and u=$\beta_0 + \beta_1\chi_1 + \beta_2\chi_2 \ldots. + \beta_k\beta_k$ is the logistic regression equation of β covariates ($\chi_1, \chi_2 \ldots. \chi_k$) significantly influencing deer sightability (Unsworth et al. 1999, Grassel 2000).

RESULTS

Spring Model

We conducted spring sightability trials between 20 April to 5 May 2009 and 8 to 14 April 2010 on 25 radiocollared deer in 2009 and 42 radiocollared deer in 2010. We recorded a total of 161 sightability observations during 7 flights; however, as time progressed canopy cover reduced visibility of deer and resulted in 19 observations censored from analysis because groups could not be detected. Thus, 142 observations were used for model development (Table 1). We observed 88 of 161 (54.7%) deer groups and missed 73 of 161 (45.3%) groups. Average group size during the spring was 4.93 deer and 76.8% of all deer groups were observed in trees.

Stepwise regression analysis indicated that group size ($P \leq 0.001$) and percent canopy cover ($P \leq 0.001$) significantly influenced sightability of deer (Table 3). The logistic regression portion of the model was:

$$y = 2.297 + 0.252\ (\text{group size}) - 1.10\ (\text{canopy cover}).$$

Other independent variables that did not influence the probability of detecting deer in the spring included animal behavior ($p \geq 0.05$), flight number ($p \geq 0.05$) and vegetation type (i.e. habitat; $p \geq 0.05$). However, canopy cover served as a quasi variable for vegetative type because the type of vegetation influenced percent canopy cover and were correlated with one another. The spring sightability model correctly classified 100% of the 142 observations as seen or missed (McFadden's Rho-Squared = 0.272). Increased group size, increased the detection probability of observing deer (Figure 2). Likewise, the probability of observing deer was greatly influenced by the percent canopy cover

(Figure 3).

Winter Model

We conducted winter sightability flights over 40 radiocollared deer between 16 to 28 February 2010 and over 29 radiocollared deer between 26 January to 4 February 2011 when 100% snow cover was present and deer were in large herds. We recorded a total of 173 sightability observations during 8 flights (Table 2). We observed 146 of 173 (84.4%) deer groups and missed 27 of 173 (15.6%) groups. Average group size during the winter was 19.4 deer and 54.9% of all deer groups were observed in trees.

Stepwise regression analysis indicated that group size ($P = 0.026$) and percent canopy cover ($P \leq 0.001$) significantly influenced sightability of deer (Table 4). The logistic regression portion of the model was:

$$y = 3.064 + 0.044 \text{ (group size)} - 1.126 \text{ (canopy cover)}.$$

Other independent variables that did not influence the probability of detecting deer in the winter included animal behavior ($p \geq 0.05$), flight number ($p \geq 0.05$) and vegetation type (i.e. habitat; $p \geq 0.05$). Likewise, canopy cover served as a quasi variable for vegetative type because they were correlated with one another. The winter sightability model correctly classified 100% of the 173 observations as seen or missed (McFadden's Rho-Squared = 0.274). Increased group size increased the detection probability of observing deer (Figure 4). Likewise, the probability of observing deer was greatly influenced by the percent canopy cover (Figure 5).

DISCUSSION

We determined that percent canopy cover and group size were the two primary factors influencing deer sightability in the agricultural landscapes of eastern South Dakota during spring (Figure 6) and winter sightability trials (Figure 7); percent canopy cover had the greatest influence on deer sightability. Similar results were documented by Samuel et al. (1987), Otten et al. (1993), Cogan and Diefenbach (1998) and Jarding (2010), where percent canopy cover had the greatest effect on elk sightability. Likewise, Anderson and Lindzey (1996) noted that percent canopy cover was the only significant predictor of moose sightability during helicopter surveys in Wyoming. Two summer elk sightability models developed by Anderson et al. (1998) indicated that percent canopy cover and group size were the primary factors affecting elk sightability.

Increased canopy cover negatively influenced deer sightability during spring and winter sightability trials in eastern South Dakota. However, deer sightability models developed by Ackerman (1998) in Idaho and Grassel (2000) in central South Dakota found that canopy cover was not a significant factor in predicting mule deer and white-tailed deer sightability. We speculate that our results were contrary to Grassel (2000) because rangeland comprised approximately 82% of the landscape and canopy cover was limited to small, disjunct patches of eastern red ceder (*Juniperus virginiana*) in the Missouri River Breaks Region of central South Dakota. Also, Ackerman (1998) noted that model results may have been affected by variable measuring techniques among observers and because canopy cover was measured vertically, even though most deer were spotted from an oblique angle. Unsworth et al. (1999) emphasized that percent canopy cover should be measured obliquely and the use of trained, consistent observers was critical for determining its effect on deer sightability.

During spring sightability trials when trees started to bud and flower, canopy cover increased significantly and detection rates decreased. On some occasions the group had to be censored from analyses because we were unable to observe deer and collect information on important variables (e.g., group size). The temporal window for conducting spring surveys is limited because deer need to complete spring migrations, color contrast between deer and vegetation should be at a maximum, but canopy cover must be at a minimum. Because of the high use and selection of trees by white-tailed deer in the agricultural landscapes of South Dakota (Chapter 4), percent canopy cover plays a significant role in deer sightability.

Our findings indicated that the number of deer in a group was positively correlated to the probability of detecting deer in both spring and summer models (Table 1, 2). Group size played a significant role in deer sightability, especially during winter when deer were in large herds (i.e., >25 individuals). Cook and Jacobson (1979) and Samuel and Pollack (1981) both noted that group size significantly influenced ungulate sightability. Unsworth et al. (1999) suggested that ungulate surveys should be conducted when group sizes are at a maximum. Moreover, Gassaway et al. (1985) noted that sightability of moose increased greatly when they were in larger groups. Group size and activity significantly influenced the probability of observing deer in Idaho and central South Dakota (Ackerman 1988, Grassel 2000). In addition, Jacques (2006) reported that group size was strongly related to the probability of detecting pronghorn groups during spring aerial surveys in western South Dakota. However, group size did not influence elk sightability in Michigan (Otten et al. 1993) potentially because large (> 30) elk groups were not common. Likewise, Bodie et al. (1995) found that group size did not influence the probability of observing bighorn sheep and noted that high levels of sightability in open terrain and behavioral adaptations of disturbed bighorn sheep may have limited the effects of group size on sightability.

Group activity (i.e., bedded, standing, moving) did not ($P \geq 0.05$) influence sightability of deer in eastern South Dakota. However, deer that were moving had an increased probability of detection compared to standing or bedded deer during spring and winter (Table 1, 2). Deer sightability models developed by Ackerman (1988) and Grassel (2000) documented group activity was a significant factor affecting sightability where canopy cover was a limited factor. Bodie et al. (1995) reported that in open terrain, moving groups of bighorn sheep were twice as likely to be detected compared to stationary sheep. Allen (2005) and Mcintosh et al. (2009) reported that elk groups exhibiting limited activity negatively influenced detection rates in Canada. Jacques (2006) reported group activity was the most influential factor in predicting pronghorn sightability in southwestern South Dakota where the effect of canopy cover was limited. We speculate group activity was a limited factor in eastern South Dakota because sightability was strongly dependent on canopy cover. If canopy cover was too high, deer were not detected regardless of activity, especially during the spring.

Because variation in snow conditions can influence detection probabilities of ungulates during aerial surveys (LeResche and Rausch 1974, Leptich and Zager 1992), we conducted winter sightability trials when 100% snow cover was present to mitigate the potential snow effect. We estimate that winter detection rates were 29.8% higher compared to spring detection rates because 100% snow cover was present, canopy cover was less, and deer were in large wintering groups. However, our spring sightability model will provide game managers with an alternative population estimate when 100% snow cover is not provided. Our research findings were similar to models developed for elk (Samuel et al. 1987, Otten 1993, Anderson et al. 1998, Mcintosh et al. 2009, Jarding 2010), oryx (Krueger et al. 2007), mountain goats (Rice et al. 2009), white-tailed deer (Grassel 2000), mule deer (Unsworth et al. 1999), bighorn sheep (Bodie et al. 1995) and moose (Gassaway et al. 1985, Anderson and Lindzey 1996).

MANAGEMENT IMPLICATIONS AND MODEL APPLICATION

Results obtained during this study indicated that group size and canopy cover were the two primary factors influencing white-tailed deer sightability in both spring and winter sightability trials. Both models developed during our study will assist game managers in determining more accurate population estimates by incorporating correction factors for groups of deer observed and missed during aerial surveys in agricultural dominated landscapes throughout similar habitat types in eastern South Dakota. Deer were sighted in the spring at a rate of 54.6% (88/161), and winter sightability rate was 84.4% (146/173); indicating increased probability of detection during winter surveys.

To reduce bias, aerial surveying procedures must rigorously follow sampling protocols established during model development. During winter, surveys can only be flown when 100% snow cover is present and deer are in large herds. Spring surveys cannot be flown if deer have not migrated back to their summer ranges and/or canopy cover becomes too thick due to emerging leaf buds. All variables (i.e., height, speed, seating arrangements) must be followed consistently with the protocol developed during winter and spring sightability trials. Additional sightability trials with radiocollared deer may need to be conducted to incorporate areas with extreme variation in habitat characteristics.

LITERATURE CITED

Ackerman, B. B. 1988. Visibility bias of mule deer aerial census procedures in southeast Idaho. Dissertation, Universtiy of Idaho, Moscow, USA.

Allen, J. R. 2005. Use of sightability models and resource selection functions to enhance aerial population surveys of Elk (*Cervus elaphus*) in Alberta. Thesis, University of Alberta, Alberta, CA

Anderson, C. R., Jr. 1994. A sightability model for moose developed from helicopter surveys in western Wyoming, Thesis, University of Wyoming, Laramie, USA.

Anderson, C. R., Jr., and F. G. Lindzey. 1996. Moose sightability model developed from helicopter surveys. Wildlife Society Bulletin 24:247-259.

Anderson, C. R., D. S. Moody, B. L. Smith, F. G. Lindzey, and R. P. Lanka. 1998. Development and evaluation of sightability models for summer elk surveys. Journal of Wildlife Management 62:1055-1066.

Bodie, W. L., E. O. Garton, E. R. Taylor, and M. McCoy. 1995. A sightability model for bighorn sheep in canyon habitats. Journal of Wildlife Management 59:832-840.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, J. D. Erb, and B. S. Haroldson. 2002. A vehicle-mounted radiotelemetry antenna system design. Wildlife Society Bulletin 30:258-262.

Bryce, S., J.M. Omernik, D.E. Pater, M.Ulmer, J. Schaar, J.Freeouf, R.Johnson, P. Kuck, and S.H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/habitat/ndsdeco/index.htm>. Accessed 26

July 2011.

Caughley, G. 1974. Bias in aerial survey. Journal of Wildlife Management 38:921-933.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, New York. USA.

Clover, M. R. 1956. Single gate deer trap. California Fish and Game 42:199-201.

Cogan, C. D. and D. R. Diefenbach. 1998. Effect of undercounting and model selection on a sightability-adjustment estimator for elk. Journal of Wildlife Management 62:269-279.

Cook, R. D., and J. O. Jacobson. 1979. A design for estimating visibility bias in aerial surveys. Biometrics 35:735-742.

DelGuidice, G. D., B. A. Mangipane, B. A. Sampson, and C. O. Kochanny. 2001. Chemical immobilization, body temperature, and post-release mortality of white-tailed deer captured by Clover trap and net-gun. Wildlife Society Bulletin 29:1147-1157.

DeYoung, C. A. 1985. Accuracy of helicopter surveys of deer in south Texas. Wildlife Society Bulletin 13:146-149.

Floyd, T. J., L. D. Mech, and M. E. Nelson. 1979. An improved method of censusing deer in deciduous-coniferous forests. Journal of Wildlife Management 43:258-261.

Gasaway, W. C., S. D. Dubois, and S. J. Harbo. 1985. Biases in aerial transect surveys for moose during May and June. Journal of Wildlife Management 49:777-784.

Grassel, Shaun M. 2000. Evaluation of methodology used to estimate population size, sex and age ratios, and mortality of white-tailed and mule deer in the Missouri River breaks region of South Dakota. Thesis, South Dakota State University, Brookings, USA.

Jacques, C. N. 2006. Evaluation of aerial transect surveys, survival, and movements of pronghorns in western South Dakota. Dissertation, South Dakota State University, Brookings, USA.

Jarding, Angela R. 2010. Population estimation procedures for elk and deer in the Black Hills, South Dakota: development of a sightability model and spotlight survey. Thesis, South Dakota State University, Brookings, USA.

Johnson, R. R., K. F. Higgins, M. L. Kjellsen, and C. R. Elliott. 1997. Eastern South Dakota wetlands. Brookings: South Dakota State University. Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/wetlands/eastwet/index.htm>. Accessed 9 July 2011.

Johnson, J. R., and G. E. Larson. 1999. Grassland plants of South Dakota and the Northern Great Plains. South Dakota State University College of Agriculture & Biological Sciences, South Dakota Agriculture Experiment Station, Brookings, USA.

Krueger, B., L. C. Bender, W. R. Gould, and P. C. Morrow. 2007. A fixed-wing sightability model for oryx in desert habitats. South African Journal of Wildlife Research 37:133-142.

Leptich, D. J. and P. Zager. 1992. Couer d'Alene elk ecology project, study II: elk sightability models. Job Completion Report W-160-R-20. Idaho Department Fish and Game, Boise. 18pp.

LeResche, R. E, and R. A. Rausch. 1974. Accuracy and precision of aerial moose censusing. Journal of Wildlife Management 38:175-182.

Mcintosh, T. E., R. C. Rosatte, J. Hamr, and D. L. Murray. 2009. Development of a sightability model for low-density elk population in Ontario, Canada. Journal of Wildlife Management 73:580-585.

Miller, S. D., E. F. Becker, and W. B. Ballard. 1987. Black and brown density estimates using modified capture and recapture techniques in Alaska. International Conference of Bear Research and Management 7:23-35.

Otten, M. R., J. B. Haufler, S. R. Winterstein, and L. C. Bender. 1993. An aerial censusing procedure and for elk in Michigan. Wildlife Society Bulletin 21:73-80.

Pollock, K. H., and W. L. Kendall. 1987. Visibility bias in aerial surveys: a review of estimation procedures. Journal of Wildlife Management 51:502-510.

Rice, C. G., K. J. Jenkins, W. Chang. 2009. A sightability model for mountain goats. Journal of Wildlife Management 73:468-478.

Samuel, M. D., and K. H. Pollock. 1981. Correction of visibility bias in aerial surveys where animals occur in groups. Journal of Wildlife Management 45:993-997.

Samuel, M. D., E. O. Garton, M. W. Schlegel, and R. G. Carson. 1987. Visibility bias during aerial surveys of elk in northcentral Idaho. Journal of Wildlife Management 51:622-630.

Severinghaus, C. A. 1949. Tooth development and wear as criteria of age in white-tailed deer. Journal of Wildlife Management 13:195-216.

Severinghaus, C. A. and E. L. Cheatum. 1956. Life and times of the white-tailed deer. Pages 57-186 *in* W. P. Taylor, editor. The Deer of North America. Stackpole Books. Harrisburg, Pennsylvania, USA.

Smith, V. J., J. A. Jenks, C. R. Berry, Jr., C. J. Kopplin, and D. M. Fecske. 2002. The South Dakota Gap Analysis Project. Final Report. Research Work Order No. 65. Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, S.D, USA.

South Dakota Office of Climatology. 2011. South Dakota climate and weather. <http://climate.sdstate.edu>. Accessed 2 May 2011.

Steinhorst, R. K. and M. D. Samuel. 1989. Sightability adjustment methods for aerial surveys of wildlife populations. Biometrics 45:415-425.

Unsworth, J. W., F. A. Leban, E. O. Garton, D. J. Leptich, and P. Zager. 1999. Aerial survey: user's manual. Electronic Edition. Idaho Department of Fish & Game, Boise, Idaho, USA.

Walsh, D. P., C. F. Page, H. Campa, III, S. R. Winterstein, and D. E. Beyer, Jr. 2009. Incorporating estimates of group size in sightability models for wildlife. Journal of Wildlife Management 73:136-143.

White, G. C. and T. M. Shenk. 2001. Population estimation with radio-marked animals *in* J. J. Millspaugh and J. M. Marzluff, editors. Radio tracking and animal populations. Academic Press, California, USA.

Table 5-1. Deer sightability results by independent variable from spring aerial survey observations (*n*=142) from Clark County in eastern South Dakota, 2009-2011.

Variable		**No. of groups**		**Visibility[a]**
		Missed	**Seen**	
Behavior				
	Moving	2	22	0.92
	Standing	27	43	0.61
	Bedded	25	23	0.48
% Canopy Cover				
	0	0	6	1.00
	1-24	8	25	0.76
	25-49	1	17	0.94
	50-74	18	37	0.67
	75-100	27	3	0.10
Group Size				
	1	12	7	0.37
	2	17	12	0.41
	3	6	15	0.71
	4	7	9	0.56
	5	5	9	0.64
	6-9	5	24	0.83
	10+	2	12	0.86
Habitat Type				
	Trees	46	63	0.58
	CRP Grasslands	0	9	1.00
	Cattails	7	4	0.36
	Pasture	0	7	1.00
	Small Grain/Hay	0	3	1.00
	Standing Corn	1	2	0.67

Visibility[a]= (no. of groups seen) / (no. of groups seen + no. of groups missed)

Table 5-2. Deer sightability results by independent variable from winter aerial survey observations (n=173) on white-tailed deer in Clark County, South Dakota, 2009-2011.

Variable		**No. of groups**		**Visibility[a]**
		Missed	**Seen**	
Behavior				
	Moving	0	23	1.00
	Standing	15	88	0.85
	Bedded	12	35	0.74
% Canopy Cover				
	0	4	74	0.95
	1-24	0	16	1.00
	25-49	5	38	0.88
	50-74	14	17	0.55
	75-100	4	1	0.20
Group Size				
	1-3	6	12	0.67
	4-6	7	29	0.81
	7-10	2	26	0.93
	10-14	6	15	0.71
	15-24	4	20	0.83
	25-39	1	22	0.96
	40-59	1	13	0.93
	60+	0	9	1.00
Habitat Type				
	Trees	23	72	0.76
	CRP	1	10	0.91
	Cattails	1	23	0.96
	Small Grain/Hay	1	13	0.93
	Standing Corn	1	13	0.93
	Harvest Crops	0	15	1.00

Visibility[a]= (no. of groups seen) / (no. of groups seen + no. of groups missed)

Table 5-3. Results from stepwise regression model from spring aerial survey observations (n=142) on white-tailed deer in Clark County, South Dakota, spring 2009 – 2010.

Variable	Parameter estimate	SE	*t*-ratio	*P*
Intercept	2.297	0.672	3.421	0.001
Group Size	0.252	0.076	3.325	0.001
% Canopy Cover	-1.1	0.219	-5.017	0.000

Table 5-4. Results from stepwise regression model from winter aerial survey observations on white-tailed deer (n=142), Clark County, South Dakota, winter 2009 – 2011.

Variable	Parameter estimate	SE	t-ratio	P
Intercept	3.064	0.611	5.018	0.000
Group Size	0.044	0.020	2.231	0.026
% Canopy Cover	-1.126	0.238	-4.733	0.000

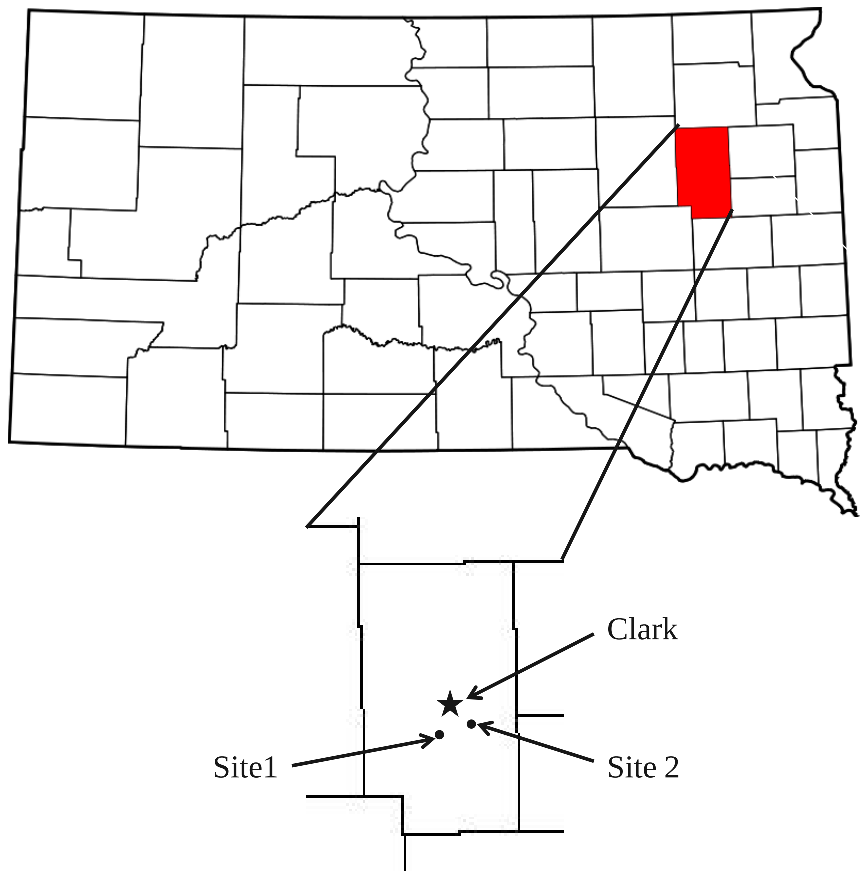


Figure 5-1. Clark County study area for white-tailed deer in eastern South Dakota. 2009-2011 including two capture sites.

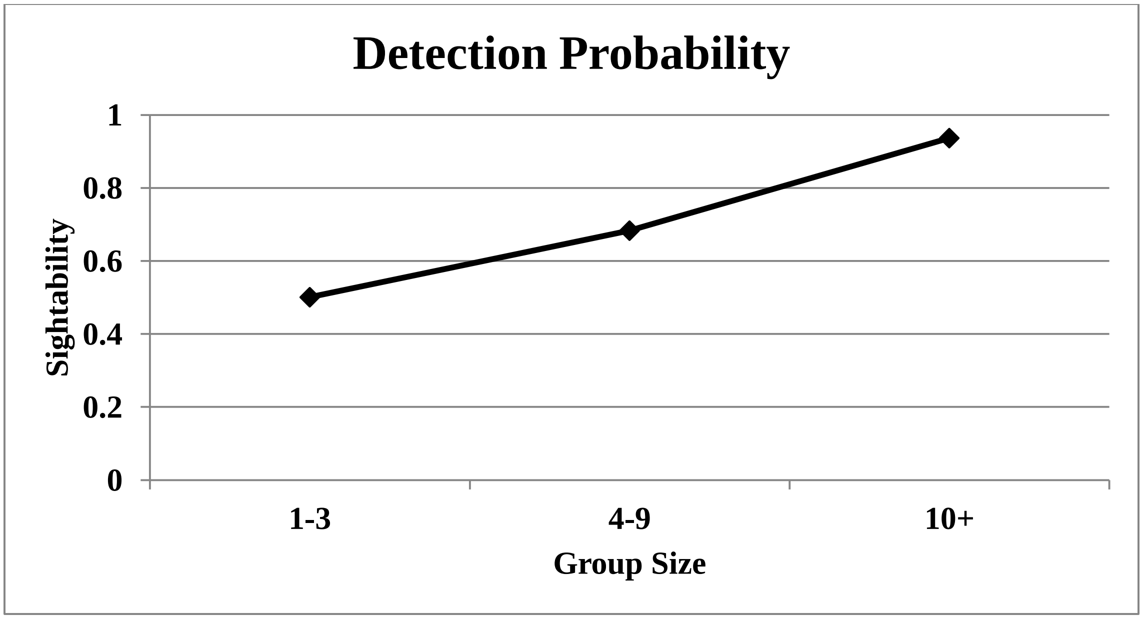


Figure 5-2. Effects of increasing group size on detection of white-tailed deer groups during sightability trials in Clark County, South Dakota, spring 2009 and 2010.

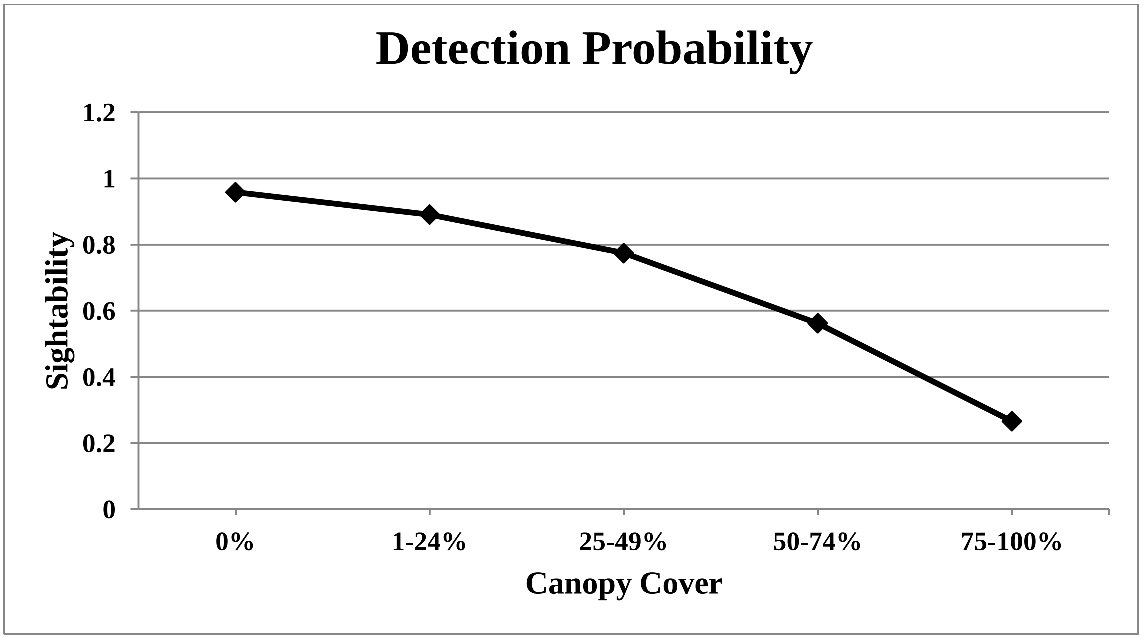


Figure 5-3. Effects of increasing percent canopy cover on detection of white-tailed deer groups during sightability trials in Clark County, South Dakota, spring 2009 and 2010.

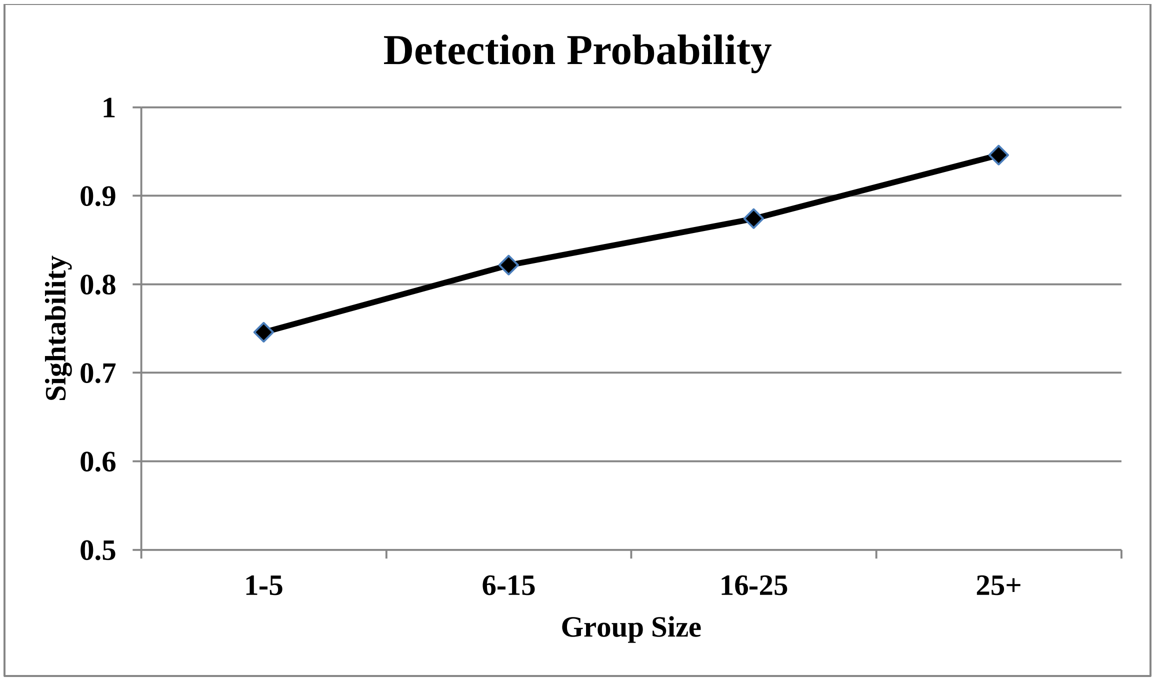


Figure 5-4. Effects of increasing group size on detection of white-tailed deer groups during sightability trials in Clark County, South Dakota, winter 2009 and 2011.

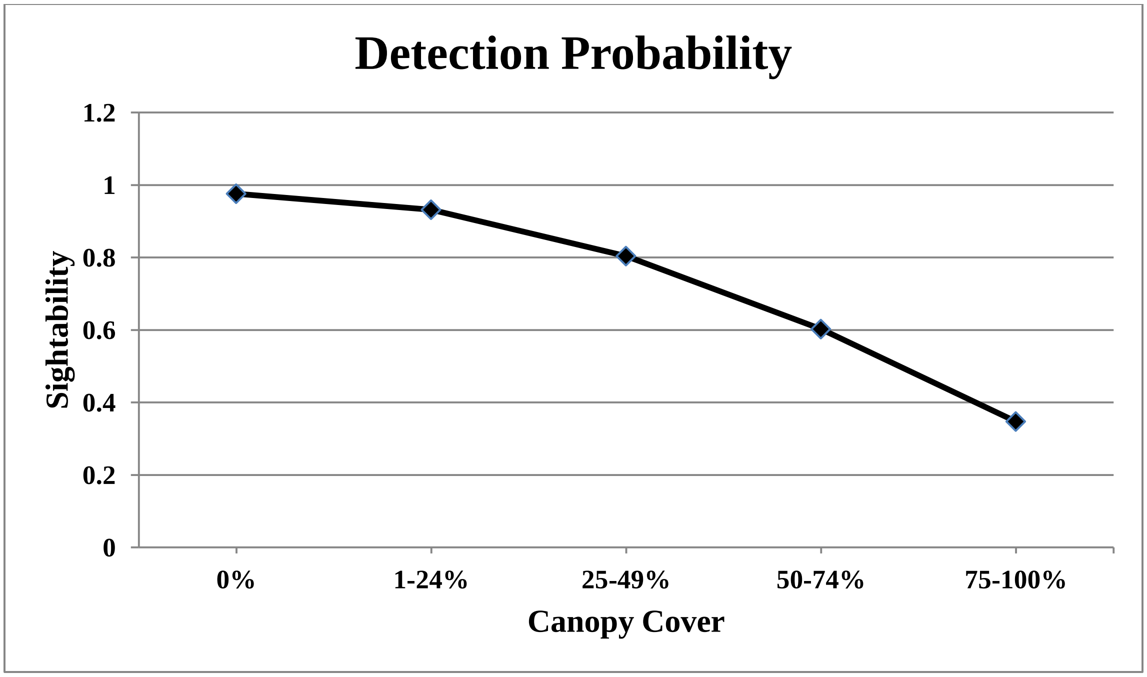


Figure 5-5. Effects of increasing percent canopy cover on detection of white-tailed deer groups during sightability trials in Clark County, South Dakota, winter 2009 and 2011.

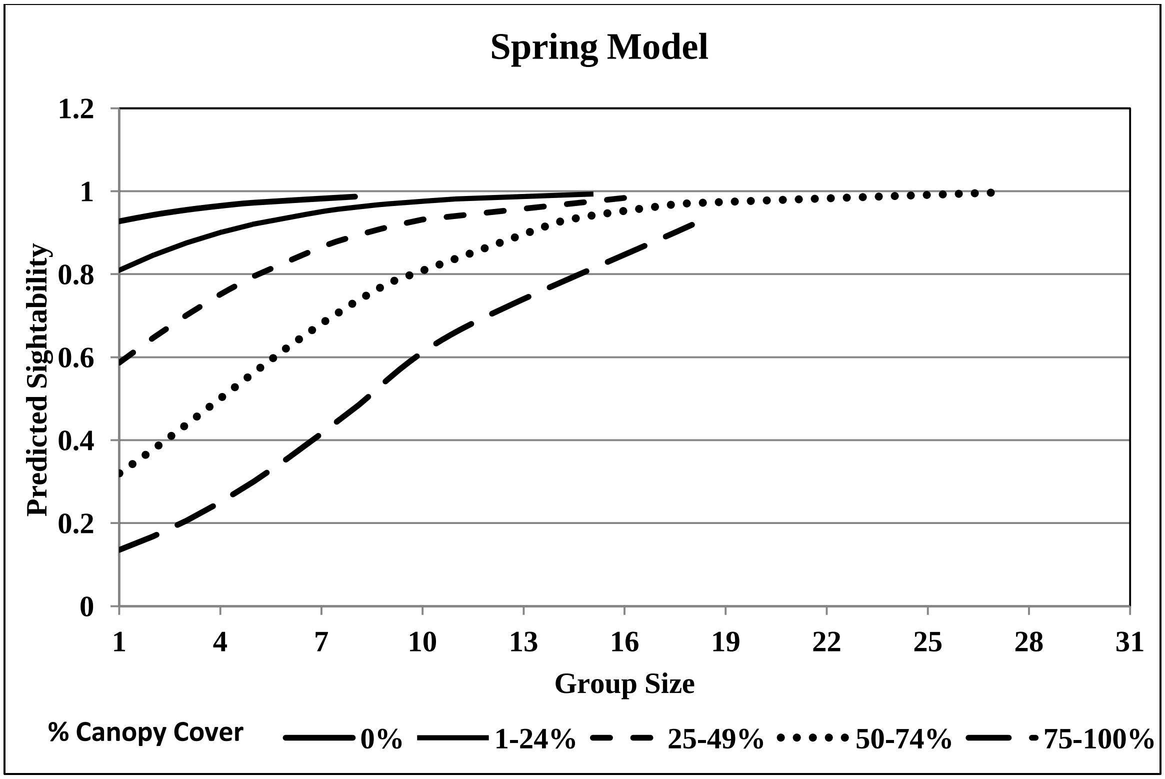


Figure 5-6. Effects of group size and increasing percent canopy cover on detection of white-tailed deer groups during sightability trials in Clark County, South Dakota, spring 2009-2010.

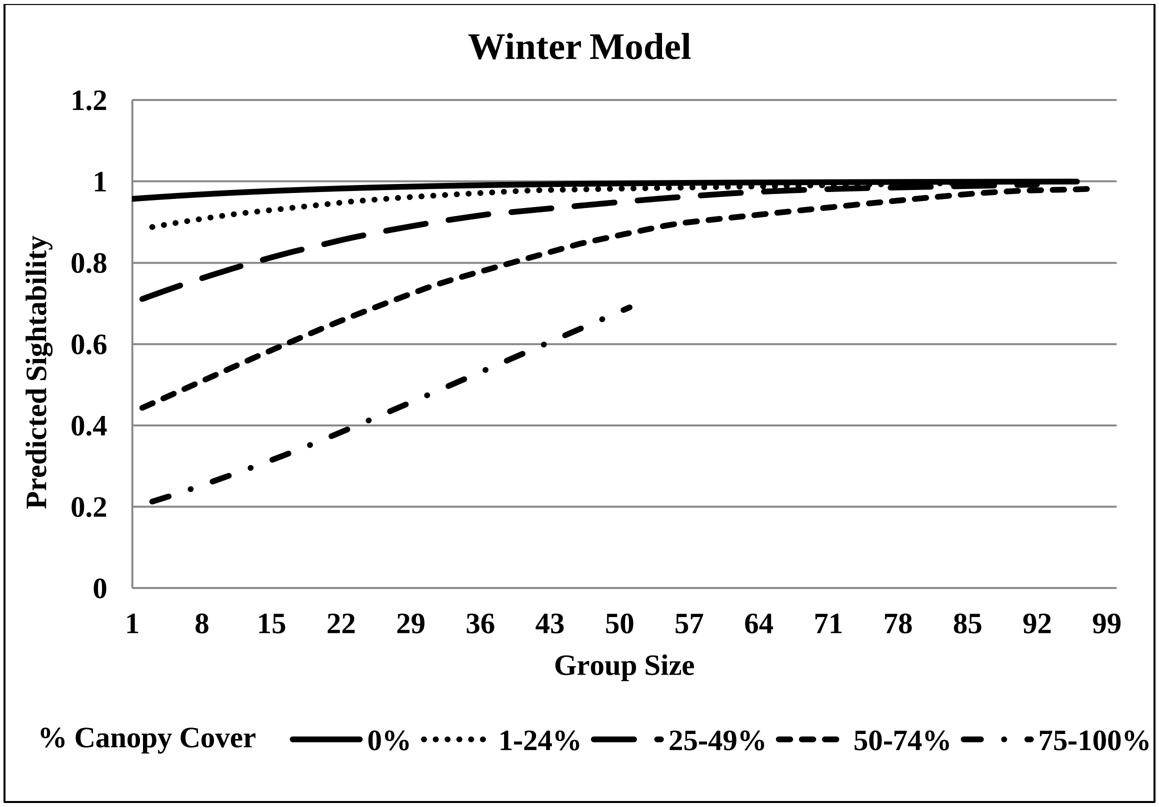


Figure 5-7. Effects of group size and increasing percent canopy cover on detection of white-tailed deer groups during sightability trials in Clark County, South Dakota, winter 2009-2011.

Appendix A. Capture data for white-tailed deer in Clark County, South Dakota, January-February 2009.

Capture Date	Collar Frequency	Capture Method	Processing Time (Minutes)	Age at Capture (Fawn, Yearling, Adult)	Sex (Male, Female)	Metal Ear Tag	Plastic Ear Tag
1/27/2009	151.335	Clover Trap	6.25	Adult	Female	625	575
1/28/2009	N/A	Clover Trap	2.25	Fawn	Male	617	556
1/29/2009	151.294	Clover Trap	N/A	Adult	Female	N/A	N/A
1/30/2009	N/A	Clover Trap	1.50	Fawn	Male	618	245
1/31/2009	N/A	Clover Trap	1.25	Yearling	Male	621	555
1/31/2009	N/A	Clover Trap	1.50	Fawn	Male	620	235
1/31/2009	151.725	Clover Trap	5.50	Yearling	Female	616	558
2/1/2009	151.116	Clover Trap	5.25	Adult	Female	624	557
2/2/2009	151.525	Clover Trap	5.00	Adult	Female	746	569
2/3/2009	N/A	Clover Trap	1.25	Fawn	Male	744	571
2/5/2009	N/A	Clover Trap	1.75	Fawn	Male	619	567
2/16/2009	150.175	Helicopter	1.25	Adult	Female	887	572
2/16/2009	150.824	Helicopter	1.75	Yearling	Female	886	249
2/16/2009	150.884	Helicopter	1.75	Adult	Female	891	574
2/16/2009	150.992	Helicopter	3.25	Yearling	Female	884	563
2/16/2009	151.014	Helicopter	4.25	Adult	Female	898	560
2/16/2009	151.074	Helicopter	3.00	Adult	Female	895	559
2/16/2009	151.093	Helicopter	2.25	Adult	Female	882	566
2/16/2009	151.136	Helicopter	1.50	Adult	Female	892	570
2/16/2009	151.154	Helicopter	2.25	Yearling	Female	899	568
2/16/2009	151.173	Helicopter	2.00	Adult	Female	889	237
2/16/2009	151.193	Helicopter	5.50	Yearling	Female	900	561
2/16/2009	151.215	Helicopter	1.75	Yearling	Female	885	246
2/16/2009	151.253	Helicopter	2.25	Adult	Female	894	562
2/16/2009	151.274	Helicopter	1.25	Adult	Female	879	36
2/16/2009	151.315	Helicopter	1.75	Yearling	Female	888	244
2/16/2009	151.405	Helicopter	1.50	Yearling	Female	883	564
2/16/2009	151.426	Helicopter	2.25	Adult	Female	897	552
2/16/2009	151.444	Helicopter	1.25	Adult	Female	896	554
2/16/2009	151.464	Helicopter	2.25	Yearling	Female	880	565
2/16/2009	151.483	Helicopter	1.50	Adult	Female	881	234
2/16/2009	151.544	Helicopter	2.00	Yearling	Female	893	573

Appendix B. Capture data for white-tailed deer in Clark County, South Dakota, January-February 2010.

Capture Date	Collar Frequency	Capture Method	Processing Time (Minutes)	Age at Capture (Fawn, Yearling, Adult)	Sex (Male, Female)	Metal Ear Tag	Plastic Ear Tag
1/8/2010	N/A	Clover Trap	2.25	Fawn	Female	715	527
1/9/2010	151.775	Clover Trap	4.50	Adult	Female	724	529
1/10/2010	150.893	Clover Trap	3.50	Yearling	Female	717	526
1/11/2010	150.194	Clover Trap	4.25	Yearling	Female	714	147
1/11/2010	N/A	Clover Trap	2.50	Fawn	Female	720	545
1/13/2010	N/A	Clover Trap	2.50	Adult	Male	673	546
1/13/2010	150.294	Clover Trap	4.25	Adult	Female	629	541
1/13/2010	150.474	Clover Trap	3.25	Adult	Female	721	547
1/15/2010	150.494	Clover Trap	3.50	Adult	Female	662	296
1/16/2010	N/A	Clover Trap	1.75	Fawn	Male	661	509
1/18/2010	N/A	Clover Trap	N/A	Fawn	Female	N/A	N/A
1/26/2010	N/A	Clover Trap	1.25	Fawn	Male	651	518
1/26/2010	N/A	Clover Trap	1.50	Fawn	Female	658	42
1/27/2010	N/A	Clover Trap	1.75	Fawn	Female	672	514
1/27/2010	150.643	Clover Trap	3.50	Adult	Female	655	513
1/28/2010	150.613	Clover Trap	3.75	Yearling	Female	657	524
1/28/2010	N/A	Clover Trap	1.50	Fawn	Female	654	523
1/29/2010	N/A	Clover Trap	1.25	Fawn	Female	665	512
1/29/2010	151.374	Clover Trap	4.25	Yearling	Female	660	504
1/29/2010	151.364	Clover Trap	3.50	Adult	Female	656	520
1/31/2010	150.154	Helicopter	2.50	Adult	Female	667	124
1/31/2010	150.662	Helicopter	1.50	Adult	Female	663	123
1/31/2010	151.574	Helicopter	1.50	Adult	Female	713	126
1/31/2010	150.264	Helicopter	3.50	Adult	Male	668	128
1/31/2010	150.343	Helicopter	2.00	Adult	Male	718	122
1/31/2010	150.534	Helicopter	3.75	Adult	Male	653	121
1/31/2010	150.735	Helicopter	3.75	Adult	Male	722	125
1/31/2010	151.766	Helicopter	2.25	Yearling	Male	659	129
2/10/2010	151.173	Clover Trap	3.50	Adult	Female	710	132
2/10/2010	151.294	Clover Trap	3.25	Adult	Female	711	143
2/10/2010	N/A	Clover Trap	1.00	Fawn	Female	712	142
2/16/2010	N/A	Clover Trap	1.25	Fawn	Male	709	141
2/24/2010	N/A	Clover Trap	1.75	Fawn	Female	702	137
2/24/2010	N/A	Clover Trap	1.50	Fawn	Female	664	139
2/25/2010	151.315	Clover Trap	4.00	Adult	Female	666	131
2/25/2010	150.935	Clover Trap	5.50	Adult	Female	N/A	150

Appendix C. Seasonal movement for individual radio-collared white-tailed deer in Clark County South Dakota, 2009. Home ranges calculated using LSCV method.

Animal	Summer 50% Home Range (km^2)	Summer 95% Home Range (km^2)	Winter 50% Home Range (km^2)	Winter 95% Home Range (km^2)	Spring Movement (km)	Fall Movement (km)
150.175	0.24	1.03	0.72	3.65	N/A	N/A
150.824	0.18	0.91	1.71	9.22	N/A	N/A
150.884	0.18	0.96	0.22	1.61	N/A	N/A
150.992	0.32	1.57	2.22	7.70	N/A	N/A
151.014	0.57	2.27	0.56	2.37	N/A	N/A
151.074	0.40	1.82	1.04	4.02	N/A	N/A
151.093	0.38	1.52	0.84	3.47	2.67	4.34
151.136	0.18	1.28	N/A	N/A	8.65	6.21
151.154	0.71	3.81	0.26	1.61	3.50	7.34
151.173	0.41	2.09	0.77	3.39	N/A	N/A
151.193	0.68	2.70	0.24	1.18	3.49	7.33
151.215	0.22	1.00	2.76	11.76	N/A	N/A
151.253	0.30	1.27	0.53	2.49	3.70	5.03
151.274	0.47	3.13	0.44	1.98	N/A	N/A
151.315	0.54	2.55	N/A	N/A	11.44	N/A
151.405	0.13	0.81	0.28	1.74	4.89	4.51
151.426	0.27	1.21	1.63	6.37	10.96	10.46
151.444	0.17	0.79	0.99	4.85	3.26	4.61
151.464	0.24	1.54	N/A	N/A	1.46	5.04
151.483	0.16	0.86	0.28	1.45	N/A	N/A
151.544	0.35	2.04	1.09	5.10	N/A	N/A
151.116	0.25	1.20	1.15	4.57	N/A	N/A
151.294	0.19	1.12	4.30	16.17	N/A	N/A
151.525	0.41	2.11	1.35	5.34	2.51	2.80
151.725	0.09	0.47	0.23	1.14	1.29	1.41

Appendix D. Seasonal movement for individual radio-collared white-tailed deer in Clark County South Dakota, 2010. Home ranges calculated using LSCV method.

Animal	Summer 50% Home Range (km^2)	Summer 95% Home Range (km^2)	Winter 50% Home Range (km^2)	Winter 95% Home Range (km^2)	Spring Movement (km)	Fall Movement (km)
150.154	0.33	1.54	0.14	0.77	N/A	N/A
150.175	0.29	1.43	0.25	1.22	N/A	N/A
150.194	0.33	1.39	0.10	0.58	N/A	N/A
150.294	0.32	1.36	0.45	1.97	N/A	N/A
150.374	0.24	1.31	1.96	7.11	N/A	N/A
150.474	0.43	2.40	0.20	1.06	N/A	N/A
150.494	0.39	1.81	0.42	1.77	3.06	2.29
150.613	0.26	1.07	0.21	0.86	2.84	N/A
150.643	0.25	0.87	0.13	0.49	2.31	N/A
150.662	0.42	2.21	0.13	0.60	N/A	N/A
150.824	0.25	1.00	0.14	0.68	N/A	N/A
150.884	0.39	1.62	0.17	1.51	N/A	N/A
150.893	N/A	N/A	0.27	1.37	5.02	N/A
150.935	0.37	1.60	0.58	2.62	N/A	N/A
150.992	0.18	0.90	0.33	1.56	N/A	N/A
151.014	0.79	3.08	0.96	4.38	N/A	N/A
151.074	0.16	0.75	0.49	2.26	N/A	N/A
151.093	0.15	0.80	1.06	4.42	3.95	3.09
151.116	0.55	2.45	0.56	1.97	N/A	N/A
151.136	0.57	2.44	0.11	0.60	6.13	4.50
151.154	0.57	2.46	0.15	0.86	7.33	3.32
151.174	0.82	3.16	0.17	0.86	12.46	11.74
151.193	0.28	1.21	0.14	0.78	7.05	N/A
151.215	0.13	0.58	0.41	1.98	N/A	N/A
151.253	0.35	1.64	0.70	3.73	5.16	3.59
151.274	0.44	1.73	0.29	1.27	N/A	N/A
151.295	0.07	0.50	0.14	0.73	5.06	4.24
151.314	0.23	1.38	N/A	N/A	3.57	3.75
151.364	0.16	1.01	1.06	3.68	5.05	N/A
151.405	0.23	1.08	0.83	3.44	4.44	N/A
151.426	0.09	0.54	0.28	1.43	10.48	N/A
151.444	0.21	0.88	0.70	3.14	4.79	N/A
151.464	0.20	0.98	0.59	2.59	4.88	1.53
151.525	0.38	1.98	0.36	1.53	3.70	3.63
151.574	0.10	0.47	0.71	3.05	1.87	2.08
151.725	0.09	0.45	0.43	1.79	1.29	0.81
151.775	0.13	0.57	0.09	0.53	N/A	N/A

Appendix E. Cause-specific mortality for radiocollared female white-tailed deer in eastern South Dakota, 2009-2011.

Age at capture	Capture date	Cause of death	Date of death
Yearling	2/16/2009	Hunting	11/22/2009
Adult	2/16/2009	Hunting	11/30/2009
Yearling	2/16/2009	Unknown	12/28/2009
Adult	1/29/2009	Hunting	1/1/2010
Yearling	2/16/2009	Predation	2/2/2010
Adult	1/27/2009	Predation	3/16/2010
Yearling	1/10/2010	Disease	4/19/2010
Yearling	2/16/2009	Hunting	11/20/2010
Adult	1/27/2010	Hunting	11/20/2010
Yearling	2/16/2009	Hunting	11/28/2010
Yearling	1/28/2010	Hunting	11/28/2010
Adult	1/29/2010	Hunting	11/28/2010
Adult	2/16/2009	Hunting	11/29/2010
Adult	2/16/2009	Hunting	11/30/2010
Adult	2/25/2010	Hunting	1/3/2011
Adult	2/16/2009	Disease	1/18/2011
Yearling	1/29/2010	Unknown	2/15/2011

Appendix F. Cause-specific mortality for ear-tagged white-tailed deer in eastern South Dakota, 2009-2011.

Age at capture	Sex	Capture date	Cause of death	Date of death
Fawn	M	2/5/2009	Vehicle Collision	10/6/2009
Adult	M	1/13/2010	Unknown	10/17/2010
Fawn	M	1/26/2010	Archery Hunting	10/24/2010