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Effects of Energy Development on Movements, Home Ranges, and Resource Selection of White-Tailed Deer in the Western Dakotas

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EFFECTS OF ENERGY DEVELOPMENT ON MOVEMENTS, HOME RANGES, AND RESOURCE SELECTION OF WHITE-TAILED DEER IN THE WESTERN DAKOTAS

BY

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

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ABSTRACT

EFFECTS OF ENERGY DEVELOPMENT ON MOVEMENTS, HOME RANGES, AND RESOURCE SELECTION OF WHITE-TAILED DEER IN THE WESTERN DAKOTAS

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Oil and natural gas development has increased in recent years and research is needed to assess potential impacts on white-tailed deer (*Odocoileus virginianus*) populations. Our objectives were to document movements, home ranges, and resource selection of female white-tailed deer in response to energy development in the western Dakotas. Our study areas included Dunn County, North Dakota, an area with current oil and gas development, and Grant County, North Dakota, and Perkins County, South Dakota, areas without current oil and gas development. We captured and fitted 150 female deer with Very High Frequency (VHF) collars across study sites, and monitored movements through radio telemetry from March 2014 to December 2015. We collected 10,729 locations from radio collared individuals, documented seasonal movements, generated 50 and 95% home ranges, mapped and ground-verified habitats within home ranges, and conducted resource selection analysis using design II (population level) and design III (home range level) analyses. Overall 50 and 95% summer home ranges were 0.79 and 3.38 km^2, respectively, overall 50 and 95% winter home ranges were 2.0 and 7.9 km^2, respectively, for migrators, and overall 50 and 95% annual home ranges were 1.09 and 4.74 km^2, respectively, for resident deer. Overall mean migration distance was 8.0 km. We suspect that home ranges and seasonal movements were influenced by habitat availability, food availability, and weather and environmental conditions. We found that at the population level, deer commonly selected areas with agricultural crops (i.e., corn and sunflowers), wetlands, and forests in summer, and areas with agricultural crops and forests in winter. At the home range level, deer generally selected forests and wetlands in summer as well as forests in winter. We found that deer in Dunn County avoided developed areas at the population level during summer 2015, as well as during summers at the home range level. We compared the distance from home range centroids and random points to oil and gas well pads within the Dunn County study area and found that home range centroids averaged 1.57 km farther from well pads than random points, indicating that white-tailed deer in Dunn County were avoiding well pads. Our results showed that white-tailed deer home ranges in Dunn County were being affected by oil and gas development, and further monitoring is needed to assess continued effects on deer populations.

CHAPTER 1: GENERAL INTRODUCTION

White-tailed deer (*Odocoileus virginianus*) can be found in a variety of habitats, from intensively farmed landscapes to woodlands to urban settings (Nixon et al. 1991). The western Dakotas hold a mosaic of habitat types, such as grasslands, wooded riparian systems, and agricultural land on which white-tailed deer can thrive. White-tailed deer can maximize their chance of reproductive success by choosing appropriate migration strategies and habitat (Fretwell 1972). Low densities of deer on the landscape in the western Dakotas have allowed deer to maximize success using resources such as forests and wetlands that may be limiting.

Recent oil development in western North Dakota has increased the number of road ways, vehicles, and people. In 2013, North Dakota produced 314 million barrels of oil from approximately 9,259 active wells and 347 million cubic feet (MCF) of natural gas from 9,753 wells (Department of Mineral Resources Oil and Gas Division 2016). Recently ranked third in counties with highest oil production, Dunn County, North Dakota, has increased from less than 600 wells in 2007 to almost 2,000 wells in 2014 (North Dakota Department of Mineral Resources 2015).

Oil and natural gas development can be detrimental to wildlife populations (Hebblewhite 2008, Northrup and Wittemyer 2013). The construction of well pads, access roads, and pipelines fragment and alters habitat that many species of wildlife need to survive. Changes in distribution, movement patterns, and stress from activities associated with energy development such as traffic, noise, and human activity also may occur (Dyer et al. 2002, Sawyer et al. 2002). Increased human access to wild lands also may entice further habitat fragmentation, resource extraction, and direct mortality of wildlife (Northrup and Wittemyer 2013).

The majority of studies focusing on effects of energy development on ungulate species have been directed at caribou (*Rangifer tarandus*; Smith et al. 1994, Dyer et al. 2002, Cameron et al. 2005), elk (*Cervus canadensis*; Van Dyke and Klein 1996, Walter et al. 2006), pronghorn (*Antilocapra americana*; Beckmann et al. 2012, 2016, Christie et al. 2015, 2017), and mule deer (*Odocoileus hemionus*; Sawyer et al. 2006, Ciuti el al. 2013, Lendrum et al. 2012, 2013, Kolar et al. 2017). There is, however, a lack of information on the effects of oil and gas development on white-tailed deer. White-tailed deer inhabit a more extensive range than any other cervid in North America. Consequently, they may react differently to energy development than other cervids. Also, region-specific information is important for managing white-tailed deer due to the variability in resource use across the range of the species and unique prairie landscapes that characterize the Northern Great Plains (Brinkman et al. 2005, Grovenburg et al. 2009).

This project investigated multiple population parameters regarding adult female deer. The primary objectives of this study were to: 1) document adult female home range sizes and movements, and 2) evaluate adult female habitat selection. We hypothesized that energy development would affect white-tailed deer movements and home ranges. We predicted that deer in areas of energy development would avoid well pads, and have larger home ranges compared to areas devoid of energy development activities. We hypothesized that resource selection would differ across seasons as well as among our three study areas due to variation in available habitats among counties. We predicted that deer in all three counties would select for agricultural crops (e.g. sunflowers and corn) during summer, thermal cover (e.g. forested areas and wetlands) and forage during winter, and avoid developed areas. We predicted that deer in Dunn County would have lower selection ratios for developed areas than the other two counties due to oil and gas development in the area.

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CHAPTER 2: EFFECTS OF ENERGY DEVELOPMENT ON MOVEMENTS AND HOME RANGES OF WHITE-TAILED DEER IN THE WESTERN DAKOTAS

ABSTRACT Oil and natural gas development has increased in recent years and research is needed to assess potential impacts on white-tailed deer (*Odocoileus virginianus*) populations. Our objectives were to document movements and home ranges of female white-tailed deer in response to energy development in the western Dakotas. Our study areas included Dunn County, North Dakota, an area with current oil and gas development, and Grant County, North Dakota, and Perkins County, South Dakota, areas without current oil and gas development. We captured and fitted 150 female deer with Very High Frequency (VHF) collars across study sites, and monitored movements through radio telemetry from March 2014 to December 2015. We collected a total of 10,729 locations from radio collared individuals, documented seasonal movements, and generated 50 and 95% home ranges. Overall 50 and 95% summer home ranges were 0.79 and 3.38 km^2, respectively, overall 50 and 95% winter home ranges were 2.0 and 7.9 km^2, respectively, for migrators, and overall 50 and 95% annual home ranges were 1.09 and 4.74 km^2, respectively, for resident deer. Overall mean migration distance was 8.0 km. We suspect that home ranges and seasonal movements were influenced by habitat availability, food availability, and weather and environmental conditions. We compared the distance from home range centroids and random points to oil and gas well pads within the Dunn County study area and found that home range centroids averaged 1.57 km farther from well pads than random points, indicating that white-tailed deer in Dunn

County were avoiding well pads. Our results showed that white-tailed deer home ranges in Dunn County were being affected by oil and gas development, and further monitoring is needed to assess continued effects on deer populations.

INTRODUCTION

Understanding patterns of animal movement across landscapes informs management relative to selection of habitats, spread of disease, and survival of wildlife species. Animals attempt to maximize their chance of reproductive success by choosing appropriate migration strategies and habitat (Fretwell 1972). Managers can develop strategies to improve wildlife survival through optimizing winter habitat and providing food sources in locations determined by the use of movement ecology data.

Knowledge of movements and home ranges also is important in determining the potential impacts of human disturbance on wildlife (Edge et al. 1985, Sawyer et al. 2006). Oil and natural gas development can be detrimental to wildlife populations (Hebblewhite 2008, Northrup and Wittemyer 2013). The construction of well pads, access roads, and pipelines fragments and alters habitat when compared to large, intact habitats that maintain complexity and function. Changes in distribution, movement patterns, and stress of animals from activities associated with energy development such as traffic, noise, and human activity also can occur (Dyer et al. 2002, Sawyer et al. 2002). Moreover, increased human access to wild lands may result in further habitat fragmentation, resource extraction, and direct mortality of wildlife (Northrup and Wittemyer 2013).

The majority of studies focusing on effects of energy development on ungulate species have been directed at caribou (*Rangifer tarandus*; Smith et al. 1994, Dyer et al.

2002, Cameron et al. 2005), elk (*Cervus canadensis*; Van Dyke and Klein 1996, Walter et al. 2006), pronghorn (*Antilocapra americana*; Beckmann et al. 2012, 2016, Christie et al. 2015, 2017), and mule deer (*Odocoileus hemionus*; Sawyer et al. 2006, Ciuti el al. 2013, Lendrum et al. 2012, 2013, Kolar et al. 2017). There is, however, a lack of information on the effects of oil and gas development on white-tailed deer. White-tailed deer inhabit a more extensive range than any other cervid in North America. Consequently, they may react differently to energy development than other cervids. Also, region-specific information is important for managing white-tailed deer due to the variability in resource use across the range of the species and unique prairie landscapes that characterize the Northern Great Plains (Brinkman et al. 2005, Grovenburg et al. 2009).

Our objectives were to document movements and home ranges of female white-tailed deer in response to energy development in the western Dakotas. Previous research has shown that mule deer increasingly avoided well pads each year during the first three years of natural gas development (Sawyer et al. 2006). Multiple studies have found that home range size increases in response to human disturbance (Kuck et al. 1985, Stephenson et al. 1996, Cole et al. 1997). Therefore, we hypothesized that energy development would affect white-tailed deer movements and home ranges. We predicted that deer in areas of energy development would avoid well pads, and have larger home ranges compared to areas devoid of energy development activities.

STUDY AREA

We established study areas in Dunn and Grant counties in southwestern North Dakota, and Perkins County in northwestern South Dakota (Figure 2-1). All three counties are located in the Northwestern Great Plains Level III Ecoregion (Bryce et al. 1998) as well as the Williston Basin Geological Formation (Figure 2-2; U.S. Geological Survey 2013). The terrain is gently rolling to hilly with occasional buttes, wooded draws, and complex stream drainage systems. The majority of the land is used for grazing cattle or growing agricultural crops. Grassland and cropland comprised 54.0% and 41.3% in Dunn County, 57.4% and 38.0% in Grant County, and 68.4% and 28.3% in Perkins County, respectively (Table 2-1; USDA 2014).

The region was dominated by native northern wheatgrass – needlegrass plains, which include species such as western wheatgrass (*Pascopyrum smithii*), thickspike wheatgrass (*Elymus lanceolatus* subsp. *lanceolatus*), needleandthread (*Hesperostipa comata*), green needlegrass (*Nassella viridula*), bluebunch wheatgrass (*Pseudoroegneria spicata*), blue grama (*Bouteloua gracilis*), and threadleaf sedge (*Carex filifolia*). Other common grass and forb species were little bluestem (*Schizachyrium scoparium*), buffalograss (*Buchloe dactyloides*), American vetch (*Vicia americana*), fringed sagewort (*Artemisia frigida*), prairie coneflower (*Ratibida columnifera*), Missouri goldenrod (*Solidago missouriensis*), and dotted gayfeather (*Liatris punctata*). Introduced grasses included smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), crested wheatgrass (*Agropyron cristatum*), and timothy (*Phleum pratense*; Johnson and Larson 2007).

Woody species included western snowberry (*Symphoricarpos occidentalis*), silver buffaloberry (*Shepherdia argentea*), leadplant (*Amorpha canescens*), skunkbrush (*Rhus aromatica*), creeping juniper (*Juniperus horizontalis*), boxelder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), eastern cottonwood (*Populus deltoides*), American elm

(*Ulmus americana*), Russian olive (*Elaeagnus angustifolia*), and eastern redcedar (*Juniperus virginiana*).

The primary harvested crops included corn (*Zea mays*), wheat (*Triticum aestivum*), sunflowers (*Helianthus annuus*), and alfalfa (*Medicago sativa*). Other crops included canola (*Brassica* spp.), barley (*Hordeum vulgare*), flaxseed (*Linum usitatissimum*), soybeans (*Glycine max*), safflower (*Carthamus tinctorius*), oats (*Avena sativa*), millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), and Sudan grass (*Sorghum bicolor* subsp. *drummondii*; USDA 2014).

In Dunn County, North Dakota, we captured female white-tailed deer in a 1,492 km^2 area in the southwestern part of the county. Annual 30-year mean precipitation was 42.8 cm and monthly 30-year mean temperature ranged from -15.2^{o} C to 28.7^{o} C (North Dakota State Climate Office 2011). Observed white-tailed deer density estimated from winter aerial surveys was 1.04 deer/km^2 in 2011 (Stillings et al. 2012). Dunn County is located in the Bakken Region of North Dakota. Oil production in Dunn County began in June of 1960. Recently, it became the third highest county in oil production for North Dakota; there are approximately 1,800 wells in Dunn County producing approximately 64 million barrels of oil and 35 MCF of natural gas annually (North Dakota Department of Mineral Resources 2015*a*).

In Grant County, North Dakota, we captured female white-tailed deer in a 1,865 km^2 area in the southwestern part of the county. Annual 30-year mean precipitation was 43.0 cm and monthly 30-year mean temperature ranged from -15.7^{o} C to 28.2^{o} C (North Dakota State Climate Office 2011). Observed white-tailed deer density estimated from winter aerial surveys was 1.78 deer/km^2 in 2011 (Stillings et al. 2012). Oil and gas wells in Grant County were capped and abandoned by the 1980s due to low productivity (Department of Mineral Resources Oil and Gas Division 2016).

In Perkins County, South Dakota, we captured female white-tailed deer in a 1,492 km^2 area in the central part of the county. Annual 30-year mean precipitation was 44.9 cm and monthly 30-year mean monthly temperature ranged from -12.1^{o}C to 30.3^{o}C (North Dakota State Climate Office 2011). White-tailed deer density was estimated at 1.2 deer/km^2 in 2015 (K. Robling, South Dakota Department of Game, Fish and Parks [SDGFP], Rapid City, South Dakota, personal communication). Oil and gas wells in Perkins County were capped and abandoned by the 1980s due to low productivity (South Dakota Department of Environment and Natural Resources 2016).

METHODS

We captured adult (>1.5-years-old) and yearling (1.5-years-old) female white-tailed deer by helicopter net gun from 24 February to 2 March 2014 (Native Range Capture Services, Elko, NV, USA) and on 14 February 2015 (Quicksilver Air Inc., Peyton, CO, USA). We captured only females because of their important role regarding population growth through reproduction. Helicopter crew members hobbled and blindfolded deer after net gunning occurred. Crew members collected blood and fitted deer with Very High Frequency (VHF) radio collars (Advanced Telemetry Systems, Inc., Isanti, MN, USA) in 2014. We also attached a numbered ear tag to each radio collar for improved visual identification of deer. In 2015, crew members transported deer below the helicopter in canvas transport bags to a processing site where we recorded rectal temperature to determine physiological stress and administered 1 ml Banamine and 3 ml BO-SE (Dr. Dan Groves, North Dakota Game and Fish Department [NDGF], Bismarck, North Dakota, personal communication), and fitted deer with a VHF radio collar before release. We estimated age based on tooth replacement for each individual (Severinghaus 1949). We followed the American Society of Mammalogists guidelines (Sikes et al. 2016) for care and use of mammals and the Institutional Animal Care and Use Committee at South Dakota State University approved all handling methods (Approval No. 13-091A).

We located radio collared deer 1-3 times per week to monitor movements and conduct home range analyses. We located deer using hand held telemetry equipment, omnidirectional whip antennas, and aerial telemetry from a fixed-wing aircraft (NDGF; American Champion Scout, Rochester, WI, USA). We collected 3-6 directional bearings using a magnetic compass (Silva Ranger CLQ, Johnson Outdoors Inc., Racine, WI, USA) and used LOCATE III (Nams 2006) software on Trimble Juno handheld GPS units (Trimble Navigation Limited, Sunnyvale, CA, USA) to obtain locations for radio collared individuals. We kept locations with error ellipses ≤20 ha for analysis to minimize the risk of overestimating home ranges (Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009). We did not locate deer during the 16.5 day deer-gun season during November in North Dakota.

Statistical Analyses

We used the adehabitatHR package in program R version 3.3.1 (R Core Team 2016; Calenge 2006) to analyze location data for radio collared deer. We used the fixed kernel method to generate 50% (core area) and 95% seasonal home ranges and used least-squares-cross-validation (LSCV) to estimate the smoothing parameter (Seaman et al. 1999).

We uploaded home range shapefiles into ArcMap (Environmental Systems Research Institute, Inc., Redlands, CA, USA) and overlaid home ranges on National Agriculture Imagery Program (NAIP) orthoimagery to assess seasonal movement patterns. We classified deer as migratory if there was no overlap between summer and winter seasonal home ranges and as residents if home ranges overlapped (Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009, Robling 2011). We defined autumn migration as movement from summer to winter range, and spring migration as movement from winter to summer range. We calculated migration distance using straight-line distance between harmonic means of seasonal home ranges and migration date using the average of the last two consecutive locations before permanent departure from a seasonal home range (Grovenburg 2007, Robling 2011). We compared home range sizes of radio collared deer among years, seasons, and counties using Analysis of Variance in program R (ANOVA; Zar 1999, Robling 2011). We considered variables significant at $\alpha \leq 0.05$.

Assessing Influence of Oil

We used the Generate Near Table analysis tool in ArcMap to measure distances from home range polygons to oil wells and roads. We imported oil well data from the North Dakota Department of Mineral Resources (2015*b*) and road data from the United States Department of Agriculture (USDA) Geospatial Data Gateway. We generated distances from home range polygons to the five nearest active oil wells and nearest road. We assigned a distance of 0 for home ranges that contained oil wells or roads.

We compared distances to oil wells and roads from random points and mean centers of home ranges to assess if females were avoiding them. We generated a 100% minimum convex polygon (MCP) around all telemetry locations. Then we created random points within the MCP and used the Generate Near Table tool in ArcMap to obtain distances from random points to the five nearest oil wells. We calculated mean centers for each home range and determined distances to the five nearest oil wells. We ran *t*-tests in program R to assess if distances to oil wells from random points were similar to distances from home range centroids. We followed the same procedure for distances to roads.

To assess whether winter severity influenced migration, we calculated a deer winter severity index (DWSI; Brinkman et al. 2005) for all study areas during the winters of 2013-2014 and 2014-2015. We assigned one point for each day the mean temperature was ≤ - 7° C and an additional point for each day snow depth was ≥ 35.0 cm from November to April in North Dakota (Brinkman el al. 2005). We calculated annual WSI from the sum of the mean monthly WSI values from November to April in South Dakota using the following formula (K. Robling, SDGFP, Rapid City, South Dakota, personal communication):

$$\text{Monthly WSI} = (\text{mean monthly temperature} * (-0.1) + 1) * (\text{total monthly snowfall})$$

We regressed the DWSI for Perkins County, South Dakota against the DWSI for Grant County, North Dakota to adjust South Dakota estimates. Index values below 50 were considered mild, values between 50 and 100 moderate, and values above 100 were considered severe winters (Brinkman et al. 2005). We also plotted snow depth and temperature against percent of deer that migrated to assess their influence on timing of migration.

RESULTS

We captured and radio collared 50 adult and yearling female white-tailed deer in each study area (n = 150 deer total) in 2014. We captured and radio collared an additional 15 adult females in Grant County, North Dakota on 14 February 2015 to supplement our sample size as a result of high mortality during the previous year.

We collected a total of 10,729 locations with error ellipses ≤20 ha (majority ≤10) from March 2014 to December 2015. We collected 3,118 locations in Dunn County, 3,672 in Grant County, and 3,939 in Perkins County. We calculated summer and annual home ranges using an average of 39 locations (range = 20 – 68). We used an average of 18 locations (range = 9 – 31) to calculate winter home ranges. We used a minimum of nine locations to calculate winter home ranges due to inaccessibility and variability in timing and duration of migrations.

Influence of Oil

We generated random points within the MCP for Dunn County (one for each home range), and compared the distances to the nearest five oil wells and roads from random points and mean centers of home ranges. Results indicated home range centroids were significantly farther ($P < 0.001$, $\bar{x} = 4.94$ km, n = 82) from oil wells than random points ($\bar{x} = 3.38$ km). Home range centroids were located approximately 1.57 km farther from well pads than random points. In contrast, distance from roads to random points ($\bar{x} = 0.631$ km) and home range centroids ($\bar{x} = 0.60$ km) were similar ($P = 0.2908$).

Home ranges in Dunn County contained few active oil wells; however, the majority of home ranges contained at least one road. Ten of 36 (27.8%) female deer had at least one active well within their home range polygons. Home ranges of three females contained multiple wells (2, 3, and 8 wells). Eleven (31%) individuals did not have roads within their 50% core areas, but at least one road occurred within corresponding 95% home ranges. Maximum distance to the nearest road was 0.65 km from a 50% core area and 0.16 km from a 95% home range.

Home Ranges

We generated 64 summer and 34 winter home ranges for migrators, 112 annual (year-long) home ranges for residents, five miscellaneous (e.g., fawning, occasional sally [Burt 1943]) home ranges, and 16 home ranges for deer with unknown migration strategies totaling 234 home ranges across study areas. For migrators, mean 50 and 95% summer home ranges were 0.79 and 3.38 km^2, respectively, whereas mean 50 and 95% winter home ranges were 2.0 and 7.9 km^2, respectively. For residents, mean 50 and 95% annual home ranges were 1.09 and 4.74 km^2, respectively (Appendix Table A-1, A-2).

Home ranges varied among seasons and between years within Dunn County. Mean 50 ($F_{1, 26}$ = 11.63, P = 0.002) and 95% ($F_{1, 26}$ = 12.52, P = 0.002) annual home ranges were larger in 2014 (1.2 and 4.91 km^2) than 2015 (0.52 and 2.14 km^2) for resident deer (Figures 2-3, 2-4). Mean 50 ($F_{1, 29}$ = 7.62, P = 0.010) and 95% ($F_{1, 29}$ = 8.305, P =0.007) annual 2014 home ranges were larger than summer 2014 home ranges (0.65 and 2.75 km^2). Mean 50 ($F_{1, 26}$ = 9.753, P = 0.004) and 95% ($F_{1, 26}$ = 10.18, P = 0.004) annual 2014 home ranges also were larger than summer 2015 home ranges (0.52 and 2.28 km^2). We found no other differences between years or among seasons for Dunn County ($P \geq 0.113$).

Home ranges varied among seasons and between years within Grant County. Mean 50 ($F_{1, 22}$ = 5.976, P = 0.023) and 95% ($F_{1, 22}$ = 5.907, P = 0.024) summer home ranges were larger in 2014 (0.99 and 4.06 km^2) than 2015 (0.42 and 1.77 km^2). Mean 50 ($F_{1, 22}$ = 5.41, P = 0.030) and 95% ($F_{1, 22}$ = 5.721, P = 0.026) annual 2014 home ranges (1.15 and 4.66 km^2) were larger than summer 2015 home ranges. Mean 50 ($F_{1, 17}$ = 9.165, P = 0.008) and 95% ($F_{1, 17}$ = 11.59, P = 0.004) annual 2015 home ranges (1.12 and 5.10 km^2) were larger than summer 2015 home ranges. Mean 50 ($F_{1, 20}$ = 12.08, P = 0.002) and 95% ($F_{1, 20}$ = 13.35, P = 0.002) winter home ranges (1.39 and 6.04 km^2) also were larger than summer 2015 home ranges. We found no other differences ($P \geq 0.163$) between years or among seasons for Grant County deer.

Home ranges varied among seasons within Perkins County. Mean 50 ($F_{1, 34}$ = 10.87, P = 0.002) and 95% ($F_{1, 34}$ = 6.796, P = 0.014) winter home ranges (3.27 and 12.46 km^2) were larger than annual 2014 home ranges (1.23 and 5.65 km^2). Mean 50 ($F_{1, 33}$ = 8.048, P = 0.008) and 95% ($F_{1, 33}$ = 5.237, P = 0.029) winter home ranges also were larger than annual 2015 home ranges (1.32 and 5.97 km^2). Mean 50 ($F_{1,7}$ = 5.325, P = 0.054) and 95% ($F_{1,7}$ = 4.539, P = 0.071) home ranges approached significance with winter (3.27 and 12.46 km^2) tending to be larger than summer 2014 (1.03 and 4.4 km^2). We found no other differences among seasons or between years for Perkins County ($P \geq$ 0.251).

Among Study Areas

Mean 50 ($F_{2, 25}$ = 2.809, P = 0.079) and 95% ($F_{2, 25}$ = 3.869, P = 0.034) summer 2015 home ranges for migrators varied among study sites. Mean 95% summer 2015 home range in Perkins County (4.99 km^2) was larger than Grant County (1.77 km^2; P = 0.026). Mean 95% summer 2015 home range in Perkins County (4.99 km^2) approached significance (P = 0.062) in being larger than Dunn County (2.28 km^2). Mean 95%

summer 2015 home range in Dunn County did not differ from Grant County (P = 0.673). Perkins County mean 50% summer 2015 home range (1.13 km^2) approached significance (P = 0.064) in being larger than Grant County (0.42 km^2). Mean 50% summer 2015 home range in Dunn County (0.52 km^2) did not differ from either Grant or Perkins counties ($P \geq 0.12$).

Mean 50 ($F_{2, 51}$ = 3.581, P = 0.035) and 95% ($F_{2, 51}$ = 4.536, P = 0.015) resident home ranges varied among study sites in 2015. Perkins County mean 50 and 95% annual home ranges (1.32 and 5.97 km^2) were larger than mean 50 and 95% annual home ranges (0.52 and 2.14 km^2) for Dunn County (P = 0.027 and 0.011). Mean 50 and 95% annual home ranges in Grant County (1.12 and 5.1 km^2) did not differ from either Perkins (P = 0.854 and 0.853) or Dunn County (P = 0.332 and 0.227) in 2015. We found no other differences ($P \geq 0.079$) in home range sizes among study sites.

Five deer occupied areas separate from their annual, summer, and winter home ranges, and in addition, we were unable to classify seven deer by migration strategy due to insufficient numbers of locations or mortality (Appendix Table A-3, A-4). These home ranges included core fawning areas (n = 2), sallies during fawning season (n = 1), annual home ranges (n = 3), summer home ranges (n = 3), separate home ranges for early and late summer (n = 5), pre-/post-winter areas (n = 1), and pre-summer areas (n = 1). Deer captured in Grant County in 2015 had unknown migration strategies; we collected an insufficient number of locations to categorize individuals as migrators or residents. Mean 50 and 95% summer home ranges for these deer were 0.65 km^2 (range = 0.08 – 1.60, n = 9) and 2.6 km^2 (range = 0.36 – 6.83, n = 9), respectively.

Seasonal Movements

We documented 36 seasonal movements in Dunn County, 26 seasonal movements in Grant County, and eight seasonal movements in Perkins County during autumn migration 2014 and spring migration 2015. Overall mean migration distance throughout the study was 8.0 km (range = 1.92 – 26.31, *n* = 54; Table 2-2).

Migration strategies, distances, and departure dates varied among study areas (Tables 2-2, 2-3). Dunn and Grant counties had the highest percentages of migrating deer (56 – 60%) while deer in Perkins County were primarily residents (86 – 91%). Mean migration distances ranged from 5.84 km in Perkins County to 8.20 and 8.89 km in Dunn and Grant counties, respectively, with an overall range of 1.92 – 26.31 km. Mean autumn migration departure dates were 6 November, 16 November, and 20 November in Dunn, Grant, and Perkins counties, respectively, with an overall range of 16 September to 28 January. Mean spring departure dates were 29 March, 13 March, and 3 March in Dunn Grant, and Perkins counties, respectively, with an overall range of 29 January to 12 May.

Winter Severity

Average deer winter severity index (DWSI) was similar among study areas. Average DWSI for the winters in 2013-2014 and 2014-2015 were 117 and 96 in Dunn County, 107 and 93 in Grant County, and 132 and 97 in Perkins County, respectively (Figure 2-5). For all three study areas, the winter of 2013-2014 was classified as severe, and the winter of 2014-2015 was classified as moderate. We saw a general trend of migration in concurrence with snow depth and temperature changes in both autumn and spring migration periods (Figures 2-6, 2-7).

DISCUSSION

Our results partially support our hypothesis that energy development influenced white-tailed deer in Dunn County. Although differences in home range sizes among study areas did not indicate any influence of energy development, deer in Dunn County did avoid well pads. Home range centroids were located farther from well pads than expected, which indicated that deer were avoiding areas associated with oil and gas development in Dunn County. Our finding is consistent with Sawyer et al. (2006) and Kolar et al. (2017) who found that mule deer were more likely to select areas farther away from well pads as development proceeded. Avoidance of well pads could be associated with the direct impact of removal of habitat, as well as indirect impacts from noise associated with the oil well pumps and activity from increased traffic and human disturbance (Sawyer et al. 2002, 2006).

This prompts the question of whether or not deer could potentially acclimate to oil and gas development, and what must occur for them to do so. Interestingly, ten individuals in our study had at least one currently active oil well within their home ranges. Spud dates (the date a drill first pierces the ground when drilling an oil well) for those wells ranged from 31 December 1979 to 22 June 2014. Due to the wide range of spud dates and that at least one well was established during our study, this suggests that the amount of time an oil well is present may not be a factor influencing acclimation for white-tailed deer. Physical barriers or suitable concealment cover habitat adjacent to well pads may allow deer to tolerate wells and associated activity. Van Dyke and Klein (1996) found that elk used adjoining ridges as physical barriers between themselves and a well site. Lendrum et al. (2012) found that mule deer in a highly developed area selected more strongly for concealment cover such as pinyon-juniper habitat than deer in low to medium-low areas of development. For mule deer in the North Dakota badlands, the strongest negative predictor of mule deer habitat use was the density of drilling rigs within 600m across all seasons (Kolar et al. 2017). Kolar et al. (2017) also observed that mule deer resource selection in response to energy development, topography, and vegetative cover was mixed among studies; suggesting these differences may relate to comparing responses of mule deer in the relatively open terrain (Pinedale Anticline in Wyoming, Sawyer et al. 2006) to the areas with greater topographic relief and vegetative cover (i.e. Piceance Basin in Colorado, Northrup et al. 2015; Little Missouri Badlands in North Dakota, Kolar et al. 2017). Of the ten deer in our study that had at least one oil well in their home ranges, nine had suitable concealment cover (i.e. riparian areas, wooded areas, sunflower and corn fields, hills, tree rows) within approximately 180 m of well pads. We postulate that in areas with suitable concealment cover such as drainages or wooded areas adjacent to well pads, deer will use that habitat to avoid associated traffic or human activity, rather than shifting their home range to avoid disturbance.

The majority of home ranges in Dunn County were either similar or smaller in size compared to Grant and Perkins counties, which did not support our hypothesis that home ranges in areas with energy development would be larger than in areas without development. Rather than effects from energy development, the variation in home range size we observed could be attributed to habitat characteristics and landscape configuration (Sparrowe and Springer 1970, Grovenburg 2007, Walter et al. 2009). The arrangement of riparian areas and woodlands in Dunn County may allow deer to utilize food, water, shelter, and space arranged in compact areas.

We may have had more comprehensive results regarding energy development if we had pre-development information on deer in our study area. Many studies recommend using a before-after-control-impact (BACI) study design, or planning out long-term studies that include pre-development data on movements, survival, and reproduction (Sawyer et al. 2002, Person et al. 2007). We were unable to utilize the BACI study design due to limited baseline data available to us. Sawyer et al. (2006) included pre-development data in their study and found that mule deer increasingly avoided oil and gas pads during the first three years of development, and deer were displaced to less suitable habitats. We hope that continued monitoring of populations will help in determining effects of oil and gas development.

Limiting resources, such as food availability, may have strongly affected home range sizes in our study. In intensely cultivated areas, Brinkman et al. (2005) found that summer home ranges were reduced due to abundant crop resources, and expanded during the winter when crops were no longer available. Likewise, VerCauteren and Hygnstrom (1998) reported female deer home ranges increased in size following corn harvest. Similar to white-tailed deer in Montana (Wood et al. 1989), Illinois (Nixon et al. 1991), northeastern North Dakota (Sternhagen 2015), and southwestern Minnesota (Brinkman et al. 2005), our radio collared deer had larger home ranges during winter than summer. We also saw a general decrease in home range size from 2014 to 2015 in Grant and Dunn counties. Because crop harvest coincides with the onset of winter, deer expand their home ranges to incorporate thermal cover and new food sources into their home ranges. We believe that moderate amounts of cropland in Grant and Dunn counties caused home ranges to fluctuate from year to year, and in Perkins County, the low amount of cropland on the landscape contributed to larger, more consistent home ranges.

Many of our radio collared deer went on excursions, or occasional sallies, at some point during the study. Usually there was no pattern to these movements and they occurred for durations of a few days to up to a month. Some sallies occurred in the time period leading up to fawning season or before permanent departure for winter range. Burt (1943) called this exploratory behavior and stated that it should not be considered part of the home range. Schaffer (2013) speculated that deer going on these sallies are performing reconnaissance to look for areas containing suitable forage that might be utilized during winter. With a history of severe winters in North Dakota, we speculate that a majority of deer going on these excursions were in search of emergency food sources for winter. We also speculate that does who have lost fawns the previous year may be searching for new or better parturition habitat.

Deer in our study exhibited varied movement strategies and migration distances among counties. For example Dunn and Grant counties comprised similar numbers of migrators compared to residents while in Perkins County residents were the majority. Perkins County had a higher percentage of resident deer (86% in 2014; 91% in 2015) than what has been reported anywhere in the Northern Great Plains (22.5%, Burris 2005; 38.2%, Grovenburg et al. 2009; 50%, Robling 2011; 67%, Schaffer 2013; 58%, Sternhagen 2015). Variables affecting movement strategy and migration distance include forage availability, severe winters, cover, and energetic costs of migration (Moen 1976, Grovenburg et al. 2009, Robling 2011, Sternhagen 2015). Frequent severe winters coupled with low availability of food sources and cover could contribute to the high proportion of resident deer in Perkins County compared to Dunn and Grant counties. Even in northern latitudes where migration is a common occurrence due to the severity of winters, deer residing in generally homogenous landscapes such as grasslands may opt to stay close to known food sources to avoid expending energy through migrations. Use of suitable forest cover in Dunn County in conjunction with substitution of unharvested corn and sunflowers as cover in both Grant and Dunn counties may explain moderate migration distances in areas dominated by grasslands.

Decreasing temperature and increasing snow depth have been repeatedly attributed to deer migrations to winter ranges (Verme 1973, DelGiudice et al. 1991, Nelson 1995, 1998, Sabine et al. 2002, Grovenburg et al. 2009, Robling 2011). In addition, spring migrations typically occur in March and April when temperatures rise and snow depth diminishes (Nelson 1995, Sabine 2002, Grovenburg et al. 2009, Robling 2011). We saw a general trend of migration occurring with changes in temperature and snow depth; however, we documented a wide range of departure dates in all three counties in our study, which suggests that snow depth and temperature are not always the primary cause for migrations. DelGiudice et al. (1991) suggested that: 1) because deer migrate at intermittent times, they have diverse physiological thresholds to temperature changes that prompt migration, and 2) that there is a relationship between physiological thresholds and nutritional status. Schaffer (2013) also suggested nutrition as a motivation for migration. We documented multiple individuals migrating in the fall in conjunction with crop harvests rather than changes in temperature (NASS 2014). We suggest that deer migration initiation may be affected generally by changes in temperature and snow depth; however, another factor affecting migration is loss of food sources.

We found two patterns emerging from our data as we move 75 to 100 km, from south to north, between study areas: 1) the percent of females migrating between summer and winter ranges increased from 14% to 57%, and 2) the median length of time spent on winter range increased from 103 to 143 days. With these findings in mind, we suggest that wintering habitat is of increasing importance in the northern Great Plains. The mean migratory distance moved between summer and winter range was about 8.0 km. A land management goal for agencies may be to encourage preservation, enhancement, and development of wintering habitat; this is particularly important in North Dakota. Optimal distribution of these wintering habitats, based upon mean migratory distances, should be no more the 7.5 to 10 km apart.

MANAGEMENT IMPLICATIONS

Managers should continue monitoring radio collared individuals to help determine if deer acclimate to oil and gas pads. Females with well pads within their home ranges provide important data regarding habitat that allows them to avoid human activity associated with well pads. Maintaining undeveloped, refuge habitat is important for deer, especially near well sites. Oil and gas activities such as drilling of wells and construction of new well pads should be minimized during periods where high quality habitat is needed such as during fawning season and winter. Newer technologies such as horizontal drilling would be beneficial because it would minimize habitat lost to well pads. Fluctuations in home range size can affect deer densities, which may impact the way managers set harvest rates. Migration distance information is important for keeping track of issues such as the spread of diseases, for example chronic wasting disease (CWD), which has been documented in Grant County. The longest migration documented in our study was 26.3

km in Grant County. By means of the longest migration distance as a reference and the locations where CWD has been documented, the disease could potentially spread into an area 2,175 km^2 around known sites.

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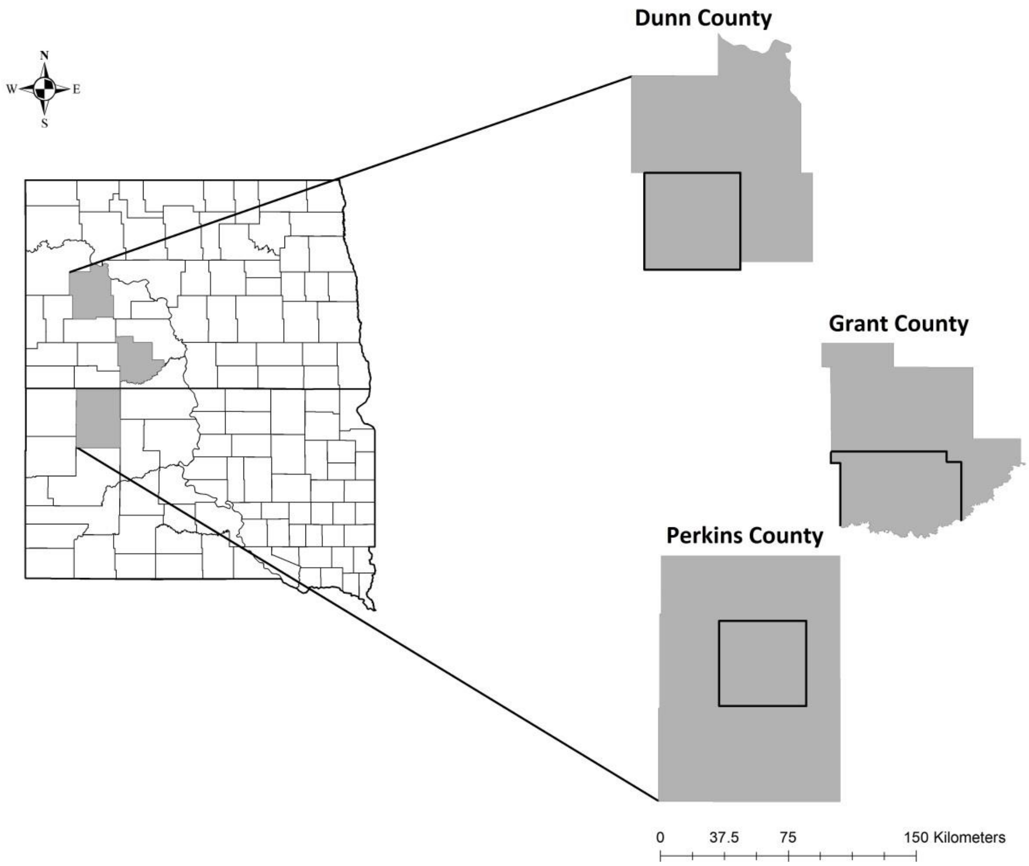

Figure 2-1. Study areas for female white-tailed deer (*Odocoileus virginianus*) located in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 and 2015.

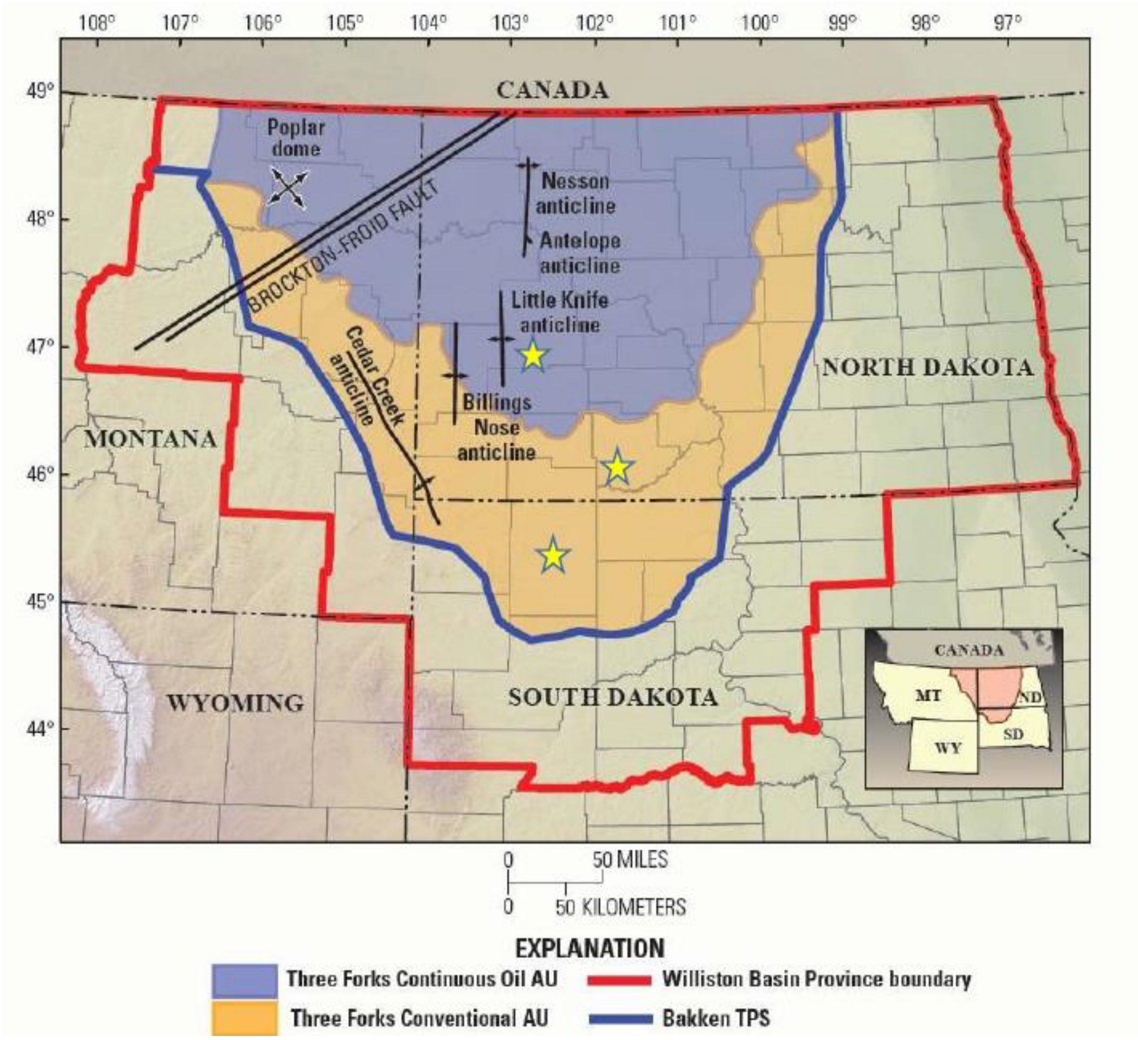

Figure 2-2. Bakken-Three Forks Formations in the Williston Basin in the Northern Great Plains (U.S. Geological Survey 2013). Yellow stars indicate study areas.

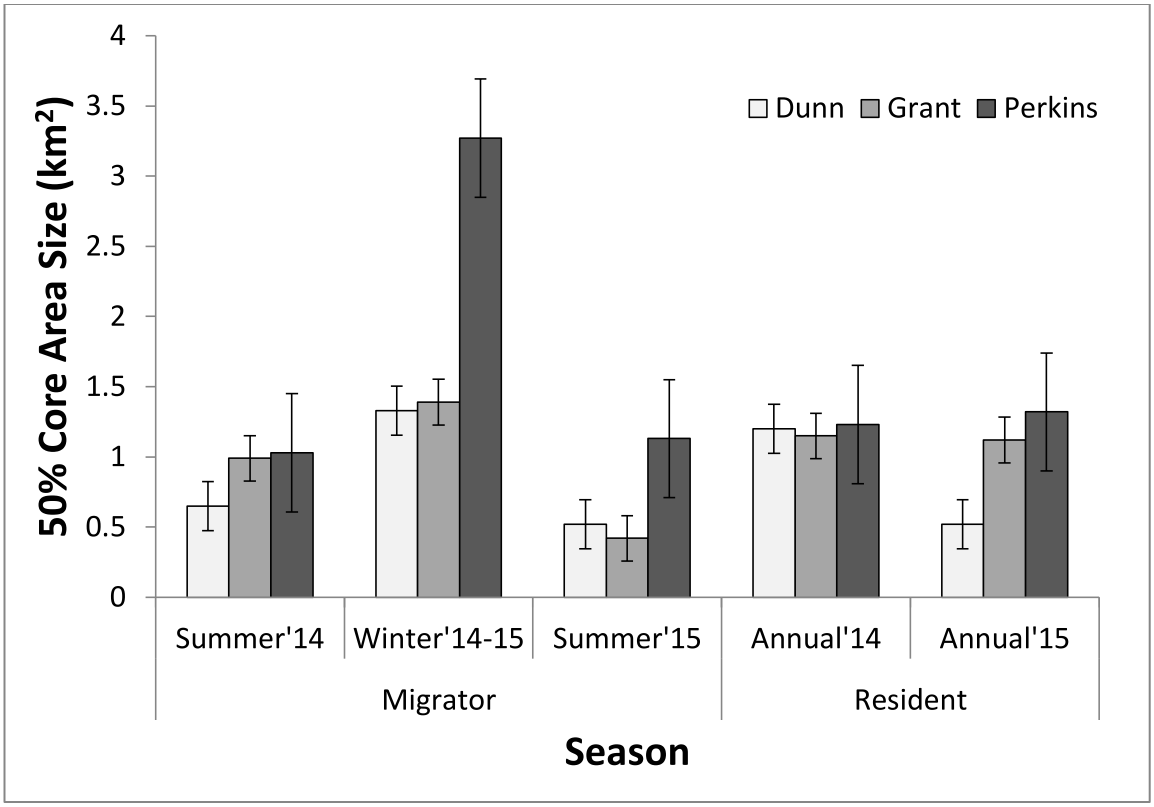

Figure 2-3. Mean seasonal 50% core areas (km^2) calculated for female white-tailed deer (*Odocoileus virginianus*) located in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 and 2015.

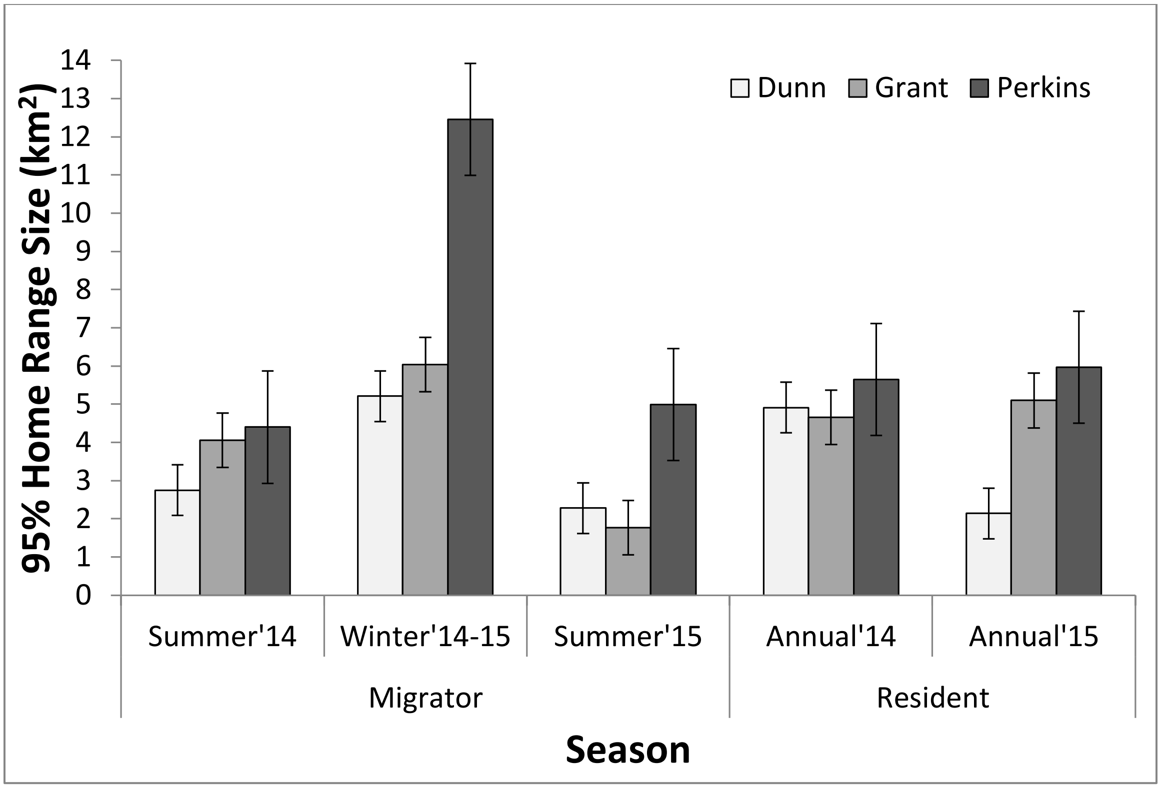

Figure 2-4. Mean seasonal 95% home ranges (km^2) calculated for female white-tailed deer (*Odocoileus virginianus*) located in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 and 2015.

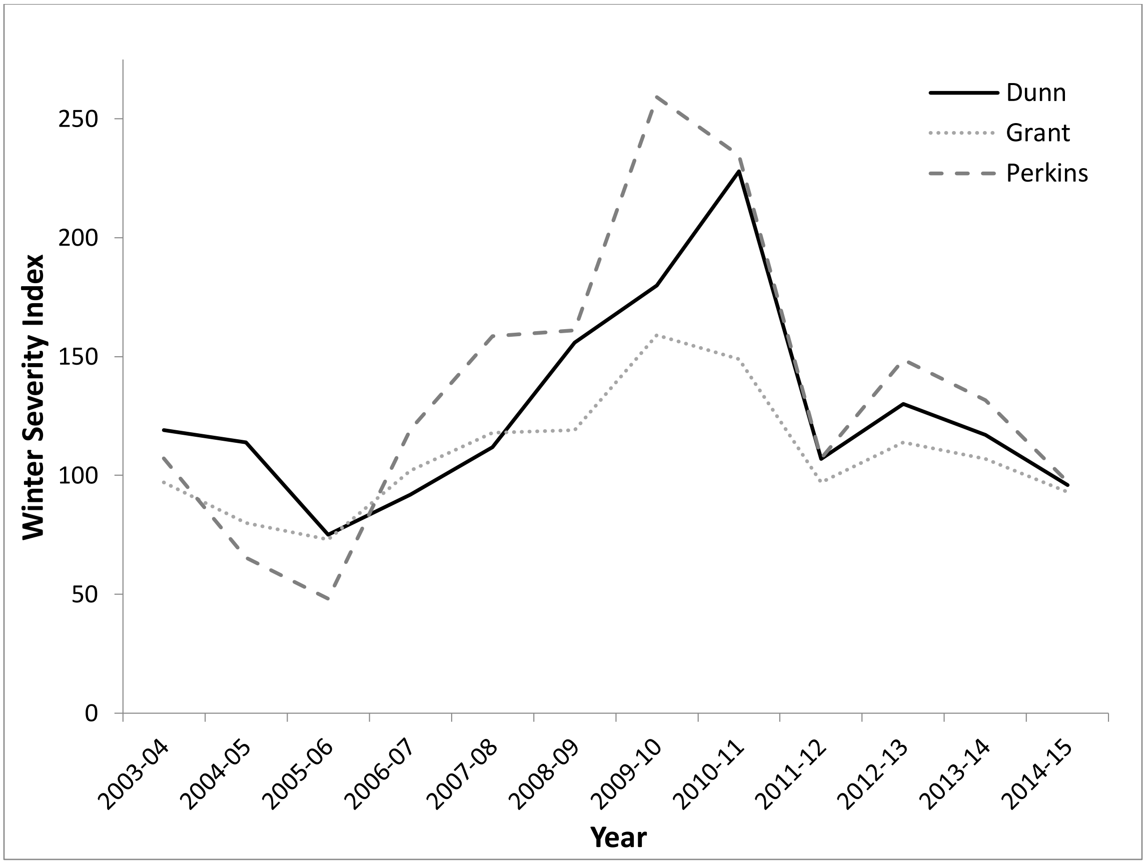

Figure 2-5. Deer winter severity indices (DWSI) plotted against the mean DWSI for the western Dakotas, USA. In North Dakota, we assigned one point for each day mean temperature was ≤ - 7° C and an additional point for each day snow depth was ≥35.0 cm (W. F. Jensen, North Dakota Game and Fish, pers. comm., Unpublished Data). In South Dakota, annual WSI was calculated from the sum of the mean monthly WSI values from November to April. Monthly WSI = (mean monthly temperature*(-0.1) + 1)*(total snowfall) (K. Robling, SDGFP, pers. comm., Unpublished Data). We regressed the DWSI for Perkins County, South Dakota against the DWSI for Grant County, North Dakota to adjust South Dakota estimations.

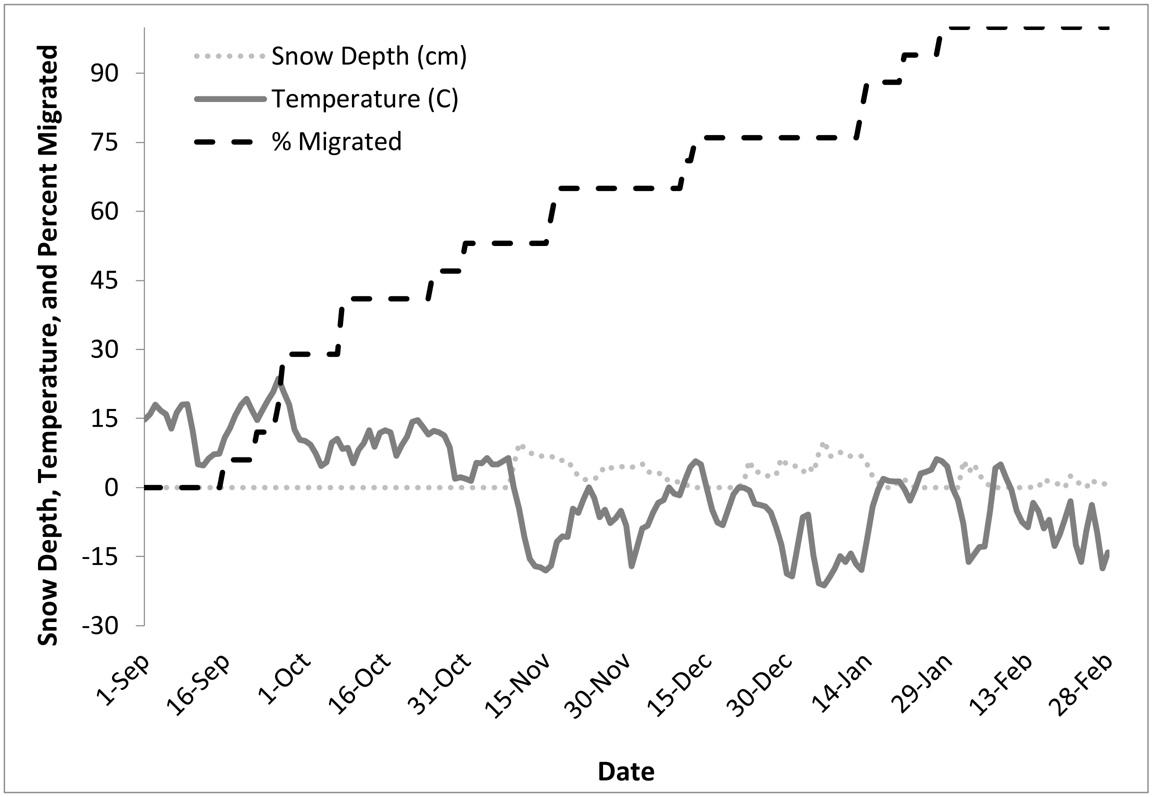

Figure 2-6. Autumn 2014 migration of female white-tailed deer (*Odocoileus virginianus*) (*n* = 17) plotted against snow depth and temperature over time in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA. We excluded migration events of deer in Grant and Dunn counties that may have been biased due to not collecting locations during the 16.5 day gun season in North Dakota.

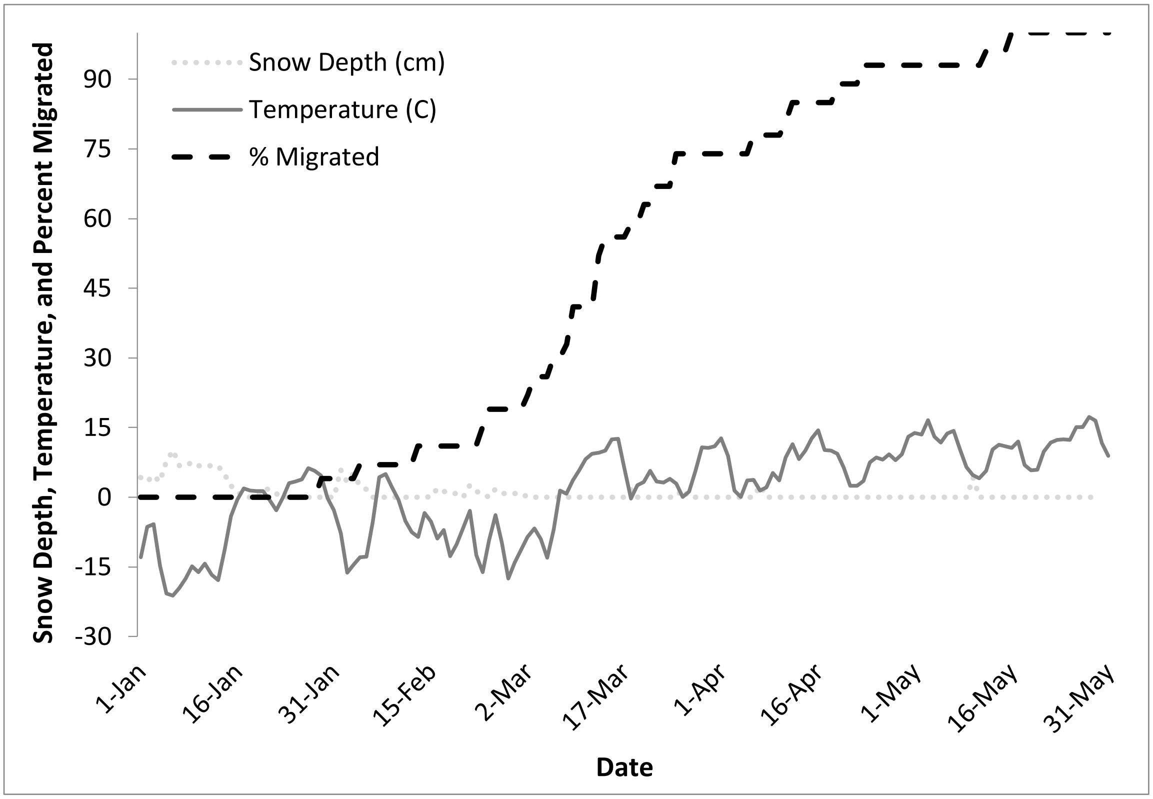

Figure 2-7. Spring 2015 migration of female white-tailed deer (*Odocoileus virginianus*) (n = 27) plotted against snow depth and temperature over time in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA.

Table 2-1. Percentages of major land use of selected study areas located in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 (USDA 2014).

	Cropland	Grassland	Forested	Wetland	Open Water	Developed	Total
Dunn	41.29%	53.97%	1.00%	0.37%	0.28%	3.08%	100%
Grant	37.95%	57.35%	0.30%	0.86%	0.29%	3.25%	100%
Perkins	28.29%	68.41%	0.09%	0.62%	1.31%	1.28%	100%

Table 2-2. Mean seasonal migration distance (km) by county for female white-tailed deer (*Odocoileus virginianus*) located in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 and 2015.

	2014 Autumn Migration (*n*, range)	2015 Spring Migration (*n*, range)
Dunn	7.36 (15, 1.92 – 13.40)	8.20 (13, 4.41 – 13.53)
Grant	8.89 (10, 3.33 – 25.65)	8.81 (10, 2.88 – 26.31)
Perkins	6.38 (4, 5.21 – 7.35)	5.84 (2, 5.26 – 6.42)
All Deer	7.75 (29, 1.92 – 25.65)	8.25 (25, 2.88 – 26.31)

Table 2-3. Mean migration departure date by female white-tailed deer (*Odocoileus virginianus*) located in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 and 2015.

County	Autumn 2014	Range (*n*)	Spring 2015	Range (*n*)
Dunn	6-Nov	9/16/14 to 1/28/15 (17)	29-Mar	3/6/15 to 5/12/15 (19)
Grant	16-Nov	9/23/14 to 1/14/15 (14)	13-Mar	2/4/15 to 5/16/15 (12)
Perkins	20-Nov	9/26/14 to 1/21/15 (5)	3-Mar	1/29/15 to 3/25/15 (3)

APPENDIX A

Table A-1. Mean 50% core areas (km^2) for female white-tailed deer (*Odocoileus virginianus*) located in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 and 2015.

	Dunn	Grant	Perkins
Summer 2014 50% (range, *n*)	0.65 (0.12 – 1.81, 18)	0.99 (0.11 – 2.25, 13)	1.03 (0.14 – 1.51, 5)
Winter 2014-15 50% (range, n)	1.33 (0.08 - 8.44, 19)	1.39 (0.39 - 3.36, 11)	3.27 (0.41 - 5.36, 4)
Summer 2015 50% (range, n)	0.52 (0.03 - 1.87, 15)	0.42 (0.10 - 0.81, 11)	1.13 (0.84 - 1.43, 2)
Annual 2014 50% (range, n)	1.2 (0.22 - 2.76, 13)	1.15 (0.13 - 3.73, 13)	1.23 (0.23 - 4.02, 32)
Annual 2015 50% (range, n)	0.52 (0.11 - 1.44, 15)	1.12 (0.17 - 2.63, 8)	1.32 (0.23 - 5.15, 31)

Table A-2. Mean 95% home ranges (km^2) for female white-tailed deer (*Odocoileus virginianus*) located in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 and 2015.

	Dunn	Grant	Perkins
Summer 2014 95% (range, *n*)	2.75 (0.60 - 5.89, 18)	4.06 (0.53 - 8.91, 13)	4.4 (0.59 - 6.25, 5)
Winter 2014-15 95% (range, n)	5.21 (0.45 - 29.28, 19)	6.04 (1.78 - 13.50, 11)	12.46 (1.53 - 20.73, 4)
Summer 2015 95% (range, n)	2.28 (0.21 - 6.98, 15)	1.77 (0.45 - 3.46, 11)	4.99 (3.92 - 6.06, 2)
Annual 2014 95% (range, n)	4.91 (0.85 - 11.08, 13)	4.66 (0.55 - 14.04, 13)	5.65 (1.10 - 17.60, 32)
Annual 2015 95% (range, n)	2.14 (0.48 - 6.01, 15)	5.1 (1.00 - 11.20, 8)	5.97 (1.40 - 20.79, 31)

Table A-3. Miscellaneous home ranges (km^2) of female white-tailed deer (*Odocoileus virginianus*) (n=5) located in Grant and Dunn counties, North Dakota, USA during 2014 and 2015.

ID	Home Range (km^2)		Year	Home Range Type	Migration Strategy
211	50%	1.24	2014-2015	Pre/Post Winter	Migrator
211	95%	4.48	2014-2015	Pre/Post Winter	Migrator
241	50%	0.09	Combined	Early Summer	Migrator
241	95%	0.4	Combined	Early Summer	Migrator
241	50%	1.28	2014	Late Summer	Migrator
241	95%	5.19	2014	Late Summer	Migrator
241	50%	1.81	2015	Late Summer	Migrator
241	95%	7.48	2015	Late Summer	Migrator
255	50%	0.3	2015	Summer Sally	Resident
255	95%	1.23	2015	Summer Sally	Resident
279	50%	0.23	2014	Fawning	Resident
279	95%	0.9	2014	Fawning	Resident
279	50%	0.32	2015	Fawning	Resident
279	95%	1.36	2015	Fawning	Resident
286	50%	0.05	2015	Pre Summer	Resident
286	95%	0.22	2015	Pre Summer	Resident

Table A-4. Home ranges (km^2) of female white-tailed deer (*Odocoileus virginianus*) (n=7) with unknown migration strategies located in Grant and Dunn counties, North Dakota, USA during 2014 and 2015.

ID	Home Range (km^2)		Year	Season
205	50%	0.62	2014	Early Summer
205	95%	2.3	2014	Early Summer
205	50%	0.86	2014	Late Summer
205	95%	3.52	2014	Late Summer
214	50%	0.79	2014	Annual
214	95%	3.28	2014	Annual
215	50%	0.57	2014	Summer
215	95%	2.88	2014	Summer
220	50%	1.26	2014	Summer
220	95%	4.81	2014	Summer
236	50%	0.66	2015	Annual
236	95%	3.29	2015	Annual
239	50%	1.37	2015	Annual
239	95%	5.33	2015	Annual
242	50%	0.44	2015	Summer
242	95%	2.15	2015	Summer

[1]Deer have unknown migration strategies due to mortality or insufficient number of locations

CHAPTER 3: RESOURCE SELECTION OF WHITE-TAILED DEER IN THE WESTERN DAKOTAS

ABSTRACT Resource selection significantly affects movements, reproductive success, and survival of wildlife species. Although resource selection of white-tailed deer (*Odocoileus virginianus*) has been studied in many regions of North America, including north-central and eastern South Dakota, limited information exists regarding populations in the western Dakotas. Oil and natural gas development has increased in recent years and has been shown to have an effect on resource selection of wildlife species. Our objective was to determine summer and winter resource selection of female white-tailed deer in southwestern North Dakota and northwestern South Dakota. Our study areas included Dunn County, North Dakota, an area with current oil and gas development, and Grant County, North Dakota, and Perkins County, South Dakota, areas without current oil and gas development. We captured and fitted 150 female deer with Very High Frequency (VHF) collars across study sites, and monitored movements through radio telemetry from March 2014 to December 2015. We collected a total of 10,729 locations from radio collared individuals, mapped and ground-verified habitats within home ranges of deer, and conducted resource selection analysis using ArcMap and program R. We analyzed resource selection at the population and home range levels using design II and III analyses, respectively. We found that at the population level, deer commonly selected areas with agricultural crops (i.e., corn and sunflowers), wetlands, and forests in summer, and areas with agricultural crops and forests in winter. At the home range level, deer generally selected forests and wetlands in summer as well as forests in winter. We found

that deer in Dunn County avoided developed areas at the population level during summer 2015, as well as during summers at the home range level. Our results indicated that thermal and escape cover, as well as agricultural crops are important to deer. Managers should ensure deer have access to such habitats, especially during harsh winters, when maintaining core temperature is essential to survival.

INTRODUCTION

Species attempt to distribute themselves and use habitats in ways that maximize success (Fretwell and Lucas 1969). Resource selection significantly affects movements, reproductive success, and survival of wildlife species (Fretwell 1972, Beier and McCullough 1990, DePerno et al. 2002). Use of information regarding change in resources and resource selection is important in guiding management decisions. Managers can use resource selection data to appropriately enhance and preserve habitats essential to white-tailed deer and other wildlife species on state owned lands, as well as to share information on land management through outreach such as brochures to private land owners and the general public.

Although resource selection of white-tailed deer has been studied in north-central (Grovenburg et al. 2010, Grovenburg et al. 2011), and eastern South Dakota (Robling 2011), limited information exists regarding populations in the western Dakotas with the exception of the Black Hills of South Dakota (DePerno et al. 2002). The western Dakotas exhibit different landscape and habitat characteristics than the previously mentioned studies, and are targeted for oil and gas development in western North Dakota, which may influence resource selection for populations of deer.

Our objective was to determine summer and winter resource selection of female white-tailed deer in the western Dakotas. Previous research has shown that deer select for high quality forage during the summer along with forage and thermal cover during the winter (Grovenburg et al. 2011, Robling 2011). We hypothesized that resource selection would differ across seasons as well as among our three study areas due to variation in available habitats among counties. We predicted that deer in all three counties would select for agricultural crops (e.g., sunflowers and corn) during summer, thermal cover (e.g., forested areas and wetlands) and forage during winter, and avoid developed areas. We predicted that deer in Dunn County would have lower selection ratios for developed areas than the other two counties due to oil and gas development in the area.

STUDY AREA

We established study areas in Dunn and Grant counties in southwestern North Dakota, and Perkins County in northwestern South Dakota (Figure 3-1). All three counties are located in the Northwestern Great Plains Level III Ecoregion (Bryce et al. 1998) as well as the Williston Basin Geological Formation (Figure 3-2; U.S. Geological Survey 2013). The terrain is gently rolling to hilly with occasional buttes, wooded draws, and complex stream drainage systems. The majority of the land is used for grazing cattle or growing agricultural crops. Grassland and cropland comprised 54.0% and 41.3% in Dunn County, 57.4% and 38.0% in Grant County, and 68.4% and 28.3% in Perkins County, respectively, in 2014 (Table 3-1; USDA 2014).

The region was dominated by native northern wheatgrass – needlegrass plains, which include species such as western wheatgrass (*Pascopyrum smithii*), thickspike wheatgrass (*Elymus lanceolatus* subsp. *lanceolatus*), needleandthread (*Hesperostipa* *comata*), green needlegrass (*Nassella viridula*), bluebunch wheatgrass (*Pseudoroegneria spicata*), blue grama (*Bouteloua gracilis*), and threadleaf sedge (*Carex filifolia*). Other common grass and forb species were little bluestem (*Schizachyrium scoparium*), buffalograss (*Buchloe dactyloides*), American vetch (*Vicia americana*), fringed sagewort (*Artemisia frigida*), prairie coneflower (*Ratibida columnifera*), Missouri goldenrod (*Solidago missouriensis*) and dotted gayfeather (*Liatris punctata*). Introduced grasses included smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*), crested wheatgrass (*Agropyron cristatum*), and timothy (*Phleum pratense*; Johnson and Larson 2007).

Woody species included western snowberry (*Symphoricarpos occidentalis*), silver buffaloberry (*Shepherdia argentea*), leadplant (*Amorpha canescens*), skunkbrush (*Rhus aromatica*), creeping juniper (*Juniperus horizontalis*), boxelder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), eastern cottonwood (*Populus deltoides*), American elm (*Ulmus americana*), Russian olive (*Elaeagnus angustifolia*), and eastern redcedar (*Juniperus virginiana*).

The primary harvested crops included corn (*Zea mays*), wheat (*Triticum aestivum*), sunflowers (*Helianthus annuus*), and alfalfa (*Medicago sativa*). Other crops included canola (*Brassica* spp.), barley (*Hordeum vulgare*), flaxseed (*Linum usitatissimum*), soybeans (*Glycine max*), safflower (*Carthamus tinctorius*), oats (*Avena sativa*), millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), and Sudan grass (*Sorghum bicolor* subsp. *drummondii*; USDA 2015).

In Dunn County, North Dakota, we captured female white-tailed deer in a 1,492 km^2 area in the southwestern part of the county. Annual 30-year mean precipitation was

42.8 cm and monthly 30-year mean temperature ranged from -15.2^{o} C to 28.7^{o} C (North Dakota State Climate Office 2011). Observed white-tailed deer density estimated from winter aerial surveys was 1.0 deer/km^2 in 2011 (Stillings et al. 2012). Dunn County is located in the Bakken Region of North Dakota. Oil production in Dunn County began in June of 1960. In 2014, the county was third highest in oil production in North Dakota; there were approximately 1,800 wells in Dunn County producing approximately 64 million barrels of oil and 35 MCF of natural gas annually (North Dakota Department of Mineral Resources 2015).

In Grant County, North Dakota, we captured female white-tailed deer in a 1,865 km^2 area in the southwestern part of the county. Annual 30-year mean precipitation was 43.0 cm and monthly 30-year mean temperature ranged from -15.7^{o} C to 28.2^{o} C (North Dakota State Climate Office 2011). Observed white-tailed deer density estimated from winter aerial surveys was 1.8 deer/km^2 in 2011 (Stillings et al. 2012). Oil and gas wells in Grant County were capped and abandoned by the 1980s due to low productivity (North Dakota Department of Mineral Resources 2016).

In Perkins County, South Dakota, we captured female white-tailed deer in a 1,492 km^2 area in the central part of the county. Annual 30-year mean precipitation was 44.9 cm and monthly 30-year mean monthly temperature ranged from -12.1^{o} C to 30.3^{o} C (North Dakota State Climate Office 2011). White-tailed deer density was estimated to be 1.2 deer/km^2 in 2015 (K. Robling, South Dakota Department of Game, Fish, and Parks [SDGFP], personal communication). Oil and gas wells in Perkins County were capped and abandoned by the 1980s due to low productivity (SDDENR 2016).

METHODS

We captured adult (>1.5-years-old) and yearling (1.5-years-old) female white-tailed deer by helicopter net gun from 24 February to 2 March 2014 (Native Range Capture Services, Elko, NV, USA) and on 14 February 2015(Quicksilver Air Inc., Peyton, CO, USA). We captured only females because of their important role regarding population growth through reproduction. Helicopter crew members hobbled and blindfolded deer after net gunning occurred. Crew members drew blood and fitted deer with Very High Frequency (VHF) radio collars (Advanced Telemetry Systems, Inc., Isanti, MN, USA) in 2014. We also attached a numbered ear tag to each radio collar to enhance visual identification of deer. In 2015, crew members transported deer below the helicopter in canvas transport bags to a processing site where we recorded rectal temperature to determine physiological stress, administered 1 ml Banamine and 3 ml BO-SE (Dr. Dan Groves, North Dakota Game and Fish Department [NDGF], personal communication), and fitted each deer with a VHF radio collar before release. We estimated age based on tooth replacement for each individual (Severinghaus 1949). We followed the American Society of Mammalogists guidelines (Sikes et al. 2016) for care and use of mammals and the Institutional Animal Care and Use Committee at South Dakota State University approved all handling methods (Approval No. 13-091A).

We located collared deer 1-3 times per week to monitor movements and collect data to conduct resource selection analyses. We located deer using hand held telemetry equipment, omnidirectional whip antennas, and aerial telemetry from a fixed-wing aircraft (NDGF, American Champion Scout, Rochester, WI, USA). We took 3-6 directional bearings using a magnetic compass (Silva Ranger CLQ, Johnson Outdoors

Inc., Racine, WI, USA) and used LOCATE III (Nams 2006) software on Trimble Juno handheld GPS units (Trimble Navigation Limited, Sunnyvale, CA, USA) to obtain locations for radio collared individuals. We kept locations with error ellipses $\leq$20 ha for analysis to minimize the risk of overestimating or misrepresenting home range data (Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2010). Obtaining accurate locations minimizes the size of error ellipses, which are then more likely to include only one habitat type (Porter and Church 1987).

We ground-verified all habitat types within each deer's home range, creating unique home range maps for summer 2014 and winter 2014 – 2015. We uploaded deer locations into ArcMap (Environmental Systems Research Institute, Inc., Redlands, CA, USA) and overlaid locations on National Agriculture Imagery Program (NAIP) orthoimagery downloaded from the United States Department of Agriculture (UDSA) Geospatial Data Gateway. We then produced maps for deer that had sufficient locations for the resource selection analysis and ground-verified habitat types in the field, outlining and labeling all land cover in areas with locations (e.g., wetlands, tree rows, agricultural crops, farms). We used the same methods to complete maps for the summer 2015 field season.

Resource Selection Analysis

We used design II (population level) and design III (home range level) analyses (Manly et al. 2002) to calculate resource selection and determine whether habitat categories were selected, avoided, or used in proportion to their availability (neutral selection) for summer 2014, winter 2014-2015, and summer 2015. We used known dates of migration from migrating deer (Chapter 2) to distinguish summer and winter seasonal ranges. We used average spring and autumn migration dates calculated from migrators to distinguish summer and winter seasonal ranges for resident deer. We calculated selection ratios ($\hat{w}$) by dividing habitat use by habitat availability (hereafter, use and availability). We defined use as the number of locations in each habitat category for individuals and availability as the percentages of habitat available at the population level for the design II analysis. For the design III analysis, we defined use as the number of locations in each habitat category for individuals and availability as the percentages of habitat available at the individual (home range) level for each deer. We defined 10 habitat categories: grass/pasture (grass, grasslands, pasturelands), forested (shrub lands, forested areas, shelterbelts), wetland, hay/alfalfa, sunflowers, corn, cereal grains (wheat, rye, barley, oats, millet), fallow (unplanted or idle cropland), other cropland (unknown fields, and any other crop that was <1% of the land cover; e.g., soybeans, safflower, canola), and developed (roads, farmsteads, oil and natural gas well pads).

We calculated availability using a minimum convex polygon (MCP) for each county for the design II analysis. We used the adehabitatHR package in program R version 3.3.1 (R Core Team 2016; Calenge 2006) to generate an MCP using all locations to represent population level availability. We imported the MCP into ArcMap and overlaid it on the 2014 Cropland Data Layer (CDL; USDA 2014) for summer 2014 and winter 2014 – 2015 analyses. We used the Tabulate Features to Percent tool (Price et al. 2010) in ArcMap to calculate percentages of available habitat for each category inside the MCP. We then repeated these methods using the 2015 CDL for the summer 2015 analysis (USDA 2015).

We calculated availability using home ranges for the design III analysis. We calculated summer home ranges using a minimum of 19 locations and winter home ranges using a minimum of 9 locations due to inaccessibility and variability in timing and duration of migrations. We used the adehabitatHR package (Calenge 2006) to generate summer 2014, winter 2014 – 2015, and summer 2015 home ranges. We used the fixed kernel method to generate 95% seasonal home ranges and used least-squares-cross-validation (LSCV) to estimate the smoothing parameter (Seaman et al. 1999). We imported home ranges into ArcMap and overlaid them on NAIP orthoimagery. We used geoprocessing and editing tools to create habitat features for each home range from our 2014 ground-verified maps. We used the Tabulate Features to Percent tool to calculate percentages of available habitat for each category within the summer 2014 and winter 2014 – 2015 home ranges. We repeated these methods using our 2015 ground-verified maps for the summer 2015 analysis.

We used program R to calculate resource selection and perform statistical analyses to compare results among counties. We used the adehabitatHS package (Calenge 2006) to calculate selection ratios ($\hat{w}$), and chi-square tests for overall deviation from random use of habitat types. We used Analysis of Variance (ANOVA; Zar 1999) to compare $\hat{w}$'s among counties for each season. We considered variables important when $\alpha \leq 0.10$ and interpreted whether habitat types were being selected for or against when confidence intervals (CIs) did not overlap 1.

RESULTS

We captured and radio collared 50 adult and yearling female white-tailed deer in each study area (n = 150 deer total). We captured and radio collared an additional 15 adult females in Grant County, North Dakota on 14 February 2015 to supplement our sample size as a result of high mortality during the previous year.

We collected a total of 10,729 locations with error ellipses ≤20 ha (majority ≤10) from March 2014 to December 2015. We collected 3,118 locations in Dunn County, 3,672 in Grant County, and 3,939 in Perkins County. We calculated summer home ranges using an average of 33 locations (range = 19 – 55) and winter home ranges using an average of 19 locations (range = 9 – 33). We completed ground-verified maps and resource selection analyses for 116 deer across all three counties. We created 3,266 habitat polygons encompassing home ranges for Dunn County, 2,794 habitat polygons for Grant County, and 1,799 habitat polygons for Perkins County.

Resource Selection – Design II

Deer in all three counties did not randomly select habitat in proportion to availability at the population level. Deer in Dunn County did not select habitat in proportion to availability during summer 2014, (χ^2 = 948.32, df = 279, $P < 0.001$), winter 2014 – 2015 (χ^2 = 839.54, df = 306, $P < 0.001$), and summer 2015 (χ^2 = 1279.68, df = 270, $P < 0.001$). Deer in Grant County did not select habitat in proportion to availability during summer 2014, (χ^2 = 1261.94, df = 324, $P < 0.001$), winter 2014 – 2015 (χ^2 = 463.23, df = 270, $P < 0.001$), and summer 2015 (χ^2 = 1335.19, df = 270, $P < 0.001$). Deer in Perkins County did not select habitat in proportion to availability during summer 2014, (χ^2 = 1018.42, df = 333, $P < 0.001$), winter 2014 – 2015 (χ^2 = 846.26, df = 378, $P < 0.001$), and summer 2015 (χ^2 = 1110.87, df = 288, $P < 0.001$).

Deer in all three counties showed variation in selection of habitats during summer 2014 (Figure 3-3). Deer in Dunn County (n = 31) selected for sunflowers ($\hat{w}$ = 3.34, CI =

1.07 – 5.61), and avoided grass/pasture ($\hat{w}$ = 0.84, CI = 0.70 – 0.98) and fallow ($\hat{w}$ = 0.51, CI = 0.03 – 0.99). Although the CI overlapped 1, there was evidence of selection for wetlands ($\hat{w}$ = 5.30, CI = 0.72 – 9.88) in Dunn County as well. Grant County individuals (*n* = 36) selected for forested ($\hat{w}$ = 7.69, CI = 1.52 – 13.85) and wetlands ($\hat{w}$ = 4.41, CI = 1.74 – 7.08), but avoided cereal grains ($\hat{w}$ = 0.63, CI = 0.43 – 0.83), developed ($\hat{w}$ = 0.52, CI = 0.26 – 0.80), fallow ($\hat{w}$ = 0.30, CI = -0.16 – 0.76), and other cropland ($\hat{w}$ = 0.16, CI = -0.13 – 0.45). There was evidence for selection of sunflowers ($\hat{w}$ = 3.31, CI = 0.84 – 5.79) in Grant County as well. Deer in Perkins County (*n* = 37) selected for corn ($\hat{w}$ = 3.42, CI = 1.62 – 5.21) and wetland ($\hat{w}$ = 3.09, CI = 1.79 – 4.39), but avoided grass/pasture ($\hat{w}$ =0.81, CI = 0.70 – 0.93), and developed ($\hat{w}$ = 0.44, CI = 0.03 – 0.86) habitats.

Selection ratios for several habitat types varied among counties during summer 2014 (Table 3-2). Forested differed among counties ($F_{2, 101}$ = 4.097, *P* = 0.02, *n* = 104) with Grant ($\bar{x}$ = 9.05) greater than both Perkins ($\bar{x}$ = 1.48, *P* = 0.02) and Dunn ($\bar{x}$ = 2.80, *P* = 0.09). Corn differed among counties ($F_{2, 101}$ = 3.94, *P* = 0.02, *n* = 104) with Perkins ($\bar{x}$ = 3.35) greater than both Grant ($\bar{x}$ = 1.42, *P* = 0.03) and Dunn ($\bar{x}$ = 1.62, *P* = 0.07). Cereal grains differed among counties ($F_{2, 101}$ = 5.51, *P* = 0.01, *n* = 104) with Perkins ($\bar{x}$ = 1.34) greater than Grant ($\bar{x}$ = 0.62, *P* = 0.004). Fallow differed among counties ($F_{2, 101}$ = 6.44, *P* = 0.002, *n* = 104) with Perkins ($\bar{x}$ = 1.29) greater than both Dunn ($\bar{x}$ = 0.55, *P* = 0.04) and Grant ($\bar{x}$ = 0.29, *P* = 0.002). We found no other differences in design II resource selection among counties during summer 2014 ($P \geq 0.12$).

Resource selection varied in all three counties during winter 2014 – 2015 (Figure 3-4). Deer in Dunn County (*n* = 34) selected for sunflowers ($\hat{w}$ = 6.86, CI = 1.71 – 12.01) and forested ($\hat{w}$ = 2.77, CI = 1.14 – 4.40), but avoided fallow ($\hat{w}$ = 0.38, CI = -0.08 – 0.84). Grant County deer (*n* = 30) selected grass/pasture ($\hat{w}$ = 1.18, CI = 1.02 – 1.34), but avoided cereal grains ($\hat{w}$ = 0.41, CI = 0.18 – 0.65) and fallow ($\hat{w}$ = 0.36, CI = -0.28 – 0.99). There was evidence of selection for forested ($\hat{w}$ = 7.37, CI = 0.25 – 14.48) in Grant County as well. Individuals in Perkins County (*n* = 42) selected for corn ($\hat{w}$ = 2.69, CI = 1.30 – 4.08), but avoided grass/pasture ($\hat{w}$ = 0.81, CI = 0.67 – 0.95). There was evidence of selection for sunflowers ($\hat{w}$ = 3.17, CI = 0.07 – 6.27) in Perkins County as well.

Selection ratios for several habitat types varied among counties during winter 2014 – 2015 (Table 3-3). Grass/pasture varied among counties ($F_{2, 103}$ = 6.52, P = 0.002, n = 106) with Grant ($\bar{x}$ = 1.14) greater than both Dunn ($\bar{x}$ = 0.87, P = 0.02) and Perkins ($\bar{x}$ = 0.81, P = 0.002). Forested varied among counties ($F_{2, 103}$ = 3.76, P = 0.03, n = 106) with Grant ($\bar{x}$ = 7.18) greater than both Dunn ($\bar{x}$ = 2.28, P = 0.10) and Perkins ($\bar{x}$ = 1.15, P = 0.02). Sunflowers varied among counties ($F_{2, 103}$ = 4.77, P = 0.01, n = 106) with Dunn ($\bar{x}$ = 7.00) greater than both Grant ($\bar{x}$ = 0.62, P = 0.009) and Perkins ($\bar{x}$ = 2.94, P = 0.10). Corn varied among counties ($F_{2, 103}$ = 4.62, P = 0.01, n = 106) with Perkins ($\bar{x}$ = 2.66) greater than Grant ($\bar{x}$ = 0.69, P = 0.009). Cereal grains varied among counties ($F_{2, 103}$ = 7.39, P = 0.001, n = 106) with Perkins ($\bar{x}$ = 1.48) greater than both Dunn ($\bar{x}$ = 0.89, P = 0.06) and Grant ($\bar{x}$ = 0.47, P < 0.001). Fallow varied among counties ($F_{2, 103}$ = 8.56, P < 0.001, n = 106) with Perkins ($\bar{x}$ = 1.56) greater than both Dunn ($\bar{x}$ = 0.34, P = 0.002) and Grant ($\bar{x}$ = 0.31, P = 0.002). We found no other differences in design II resource selection among counties during winter 2014 - 2015 ($P \geq 0.11$).

Deer in all three counties showed variation in selection of habitats during summer 2015 (Figure 3-5). Dunn County individuals (*n* = 30) selected for sunflowers ($\hat{w}$ = 5.50, CI = 1.60 – 9.41), forested ($\hat{w}$ = 5.37, CI = 1.90 – 8.83), and wetlands ($\hat{w}$ = 4.84, CI = 1.58 – 8.09), but avoided cereal grains ($\hat{w}$ = 0.57, CI = 0.31 – 0.84) and developed ($\hat{w}$ = 0.51, CI = 0.25 – 0.77) habitats. Deer in Grant County (*n* = 30) selected for forested ($\hat{w}$ = 8.22, CI = 3.35 – 13.09) and wetlands ($\hat{w}$ = 3.97, CI = 1.44 – 6.50), but avoided developed ($\hat{w}$ = 0.50, CI = 0.13 – 0.87) and other cropland ($\hat{w}$ = 0.29, CI = -0.05 – 0.62). There was evidence of selection for sunflowers ($\hat{w}$ = 2.65, CI = 0.77 – 4.52) in Grant County as well. Perkins County deer (*n* = 32) selected for fallow ($\hat{w}$ = 2.67, CI = 1.39 – 3.95) and cereal grains ($\hat{w}$ = 2.02, CI = 1.20 – 2.84), but avoided grass/pasture ($\hat{w}$ = 0.72, CI = 0.59 – 0.85) and developed ($\hat{w}$ = 0.18, CI = -0.16 – 0.51) habitats.

Selection ratios for several habitat categories differed among counties during summer 2015 (Table 3-4). Grass/pasture varied among counties ($F_{2, 89}$ = 2.59, P = 0.08, n = 92) with Grant ($\bar{x}$ = 0.92) greater than Perkins ($\bar{x}$ = 0.72, P = 0.07). Wetlands varied among counties ($F_{2, 89}$ = 3.88, P = 0.02, n = 92) with Dunn ($\bar{x}$ = 5.09) greater than Perkins ($\bar{x}$ = 1.45, P = 0.03). Hay/alfalfa varied among counties ($F_{2, 89}$ = 2.47, P = 0.09, n = 92) with Perkins ($\bar{x}$ = 1.15) greater than Grant ($\bar{x}$ = 0.68, P = 0.07). Cereal grains differed among counties ($F_{2, 89}$ = 12.9, $P < 0.001$, n = 92) with Perkins ($\bar{x}$ = 2.01) greater than both Dunn ($\bar{x}$ = 0.56, $P < 0.001$) and Grant ($\bar{x}$ = 0.83, $P < 0.001$). Fallow differed among counties ($F_{2, 89}$ = 6.06, P = 0.003, n = 92) with Perkins ($\bar{x}$ = 2.68) greater than both Dunn ($\bar{x}$ = 1.10, P = 0.04) and Grant ($\bar{x}$ = 0.60, P = 0.004). We found no other differences in design II resource selection among counties during summer 2015 ($P \geq 0.12$).

Resource Selection – Design III

Deer in all three counties did not randomly select habitat in proportion to availability at the 95% home range level. Deer in Dunn County did not select habitat in proportion to availability during summer 2014 (χ^2 = 164.10, df = 129, P = 0.02), winter 2014 – 2015 (χ^2 = 127.63, df = 93, P = 0.01), and summer 2015 (χ^2 = 173.55, df = 117, $P \leq 0.001$). Deer in Grant County did not select habitat in proportion to availability during summer 2014 (χ^2 = 231.67, df = 147, $P \leq 0.001$), winter 2014 – 2015 (χ^2 = 103.51, df = 63, $P \leq 0.001$), and summer 2015 (χ^2 = 352.81, df = 144, $P \leq 0.001$). Deer in Perkins County did not select habitat in proportion to availability during summer 2014 (χ^2 = 302.71, df = 147, $P \leq 0.001$), winter 2014 – 2015 (χ^2 = 113.12, df = 88, P = 0.04), and summer 2015 (χ^2 = 121.76, df = 126, P = 0.59).

Resource selection was similar in all three counties, but avoidance of habitat types varied during summer 2014 (Figure 3-6). Deer in Dunn County (n = 31) selected for forested ($\hat{w}$ = 2.18, CI = 1.60 – 2.76) and wetlands ($\hat{w}$ = 1.42, CI = 1.04 – 1.80), but avoided cereal grains ($\hat{w}$ = 0.77, CI = 0.63 – 0.92), developed ($\hat{w}$ = 0.43, CI = -0.07 – 0.93), and other cropland ($\hat{w}$ = 0.35, CI = -0.10 – 0.80). Grant County individuals (n = 31) selected for forested ($\hat{w}$ = 2.87, CI = 2.11 – 3.64) and wetlands ($\hat{w}$ = 1.66, CI = 1.07 – 2.26), but avoided grass/pasture ($\hat{w}$ = 0.84, CI = 0.73 – 0.96), cereal grains ($\hat{w}$ = 0.73, CI = 0.58 – 0.87), fallow ($\hat{w}$ = 0.62, CI = 0.40 – 0.84), and other cropland ($\hat{w}$ = 0.19, CI = -0.31 – 0.70). Deer in Perkins County (n = 37) selected for forested ($\hat{w}$ = 3.32, CI = 2.36 – 4.28) and wetlands ($\hat{w}$ = 2.62, CI = 1.91 – 3.32), but avoided grass/pasture ($\hat{w}$ = 0.89, CI = 0.80 – 0.99), cereal grains ($\hat{w}$ = 0.72, CI = 0.50 – 0.94), hay/alfalfa ($\hat{w}$ = 0.60, CI = 0.39 – 0.82), and developed ($\hat{w}$ = 0.24, CI = -0.09 – 0.57).

Selection ratios for several habitat categories differed among counties during summer 2014 (Table 3-5). Forested differed among counties ($F_{2, 96} = 3.20$, $P = 0.05$, $n = 99$) with Perkins ($\bar{x} = 5.69$) greater than Dunn ($\bar{x} = 2.34$, $P = 0.04$). Wetlands differed among counties ($F_{2, 96} = 8.28$, $P < 0.001$, $n = 99$) with Perkins ($\bar{x} = 2.75$) greater than both Dunn ($\bar{x} = 1.34$, $P = 0.002$) and Grant ($\bar{x} = 1.35$, $P = 0.002$). Corn differed among counties ($F_{2, 96} = 2.57$, $P = 0.08$, $n = 99$) with Grant ($\bar{x} = 1.03$) greater than Dunn ($\bar{x} = 0.50$, $P = 0.07$). Cereal grains differed among counties ($F_{2, 96} = 2.60$, $P = 0.08$, $n = 99$) with Grant ($\bar{x} = 0.78$) greater than Perkins ($\bar{x} = 0.51$, $P = 0.06$). Fallow differed among counties ($F_{2, 96} = 2.67$, $P = 0.07$, $n = 99$) with Grant ($\bar{x} = 0.44$) greater than Perkins ($\bar{x} = 0.00$, $P = 0.06$). Other cropland differed among counties ($F_{2, 96} = 6.92$, $P = 0.002$, $n = 99$) with Perkins ($\bar{x} = 0.57$) greater than both Dunn ($\bar{x} = 0.06$, $P = 0.007$) and Grant ($\bar{x} = 0.04$, $P = 0.005$). We found no other differences in design III resource selection among counties during summer 2014 ($P \geq 0.16$).

Proportions of available habitats varied among counties at the home range level during summer 2014 (Table 3-6). Available grass/pasture varied among counties ($F_{2, 96} = 13.78$, $P < 0.001$, $n = 99$) with Perkins ($\bar{x} = 59.68$) greater than both Dunn ($\bar{x} = 37.63$, $P < 0.001$) and Grant ($\bar{x} = 41.65$, $P < 0.001$). Available wetlands varied among counties ($F_{2, 96} = 2.78$, $P = 0.07$, $n = 99$) with Dunn ($\bar{x} = 6.23$) greater than Perkins ($\bar{x} = 3.50$, $P = 0.06$). Available sunflowers varied among counties ($F_{2, 96} = 3.21$, $P = 0.04$, $n = 99$) with Grant ($\bar{x} = 7.76$) greater than Perkins ($\bar{x} = 1.68$, $P = 0.06$). Available cereal grains varied among counties ($F_{2, 96} = 5.51$, $P = 0.01$, $n = 99$) with Dunn ($\bar{x} = 24.97$) greater than both Grant ($\bar{x} = 16.76$, $P = 0.05$) and Perkins ($\bar{x} = 14.52$, $P = 0.01$). Available fallow varied among counties ($F_{2, 96} = 7.73$, $P < 0.001$, $n = 99$) with Grant ($\bar{x} = 4.89$) greater than

Perkins ($\bar{x}$ = 0.00, P < 0.001). Available other cropland varied among counties ($F_{2, 96}$ = 6.56, P = 0.002, n = 99) with Perkins ($\bar{x}$ = 2.62) greater than both Dunn ($\bar{x}$ = 0.67, P = 0.01) and Grant ($\bar{x}$ = 0.57, P = 0.01). Available developed varied among counties ($F_{2, 96}$ = 7.32, P = 0.001, n = 99) with Dunn ($\bar{x}$ = 1.64) greater than both Grant ($\bar{x}$ = 0.62, P < 0.001) and Perkins ($\bar{x}$ = 1.06, P = 0.07). We found no other differences in available habitats among counties during summer 2014 ($P \geq 0.13$).

Resource selection was similar for Dunn and Grant counties, but varied from Perkins County during winter 2014 -2015 (Figure 3-7). Deer in Dunn county (n = 30) selected for forested ($\hat{w}$ = 2.50, CI = 1.83 – 3.17), but avoided hay/alfalfa ($\hat{w}$ = 0.77, CI = 0.55 – 0.98), cereal grains ($\hat{w}$ = 0.73, CI = 0.56 – 0.89), fallow ($\hat{w}$ = 0.48, CI = 0.09 – 0.86), and other cropland ($\hat{w}$ = 0.15, CI = -0.22 – 0.52). Grant County individuals (n = 20) selected for forested ($\hat{w}$ = 4.23, CI = 2.52 – 5.94), but avoided cereal grains ($\hat{w}$ = 0.50, CI = 0.26 – 0.74), other cropland ($\hat{w}$ = 0.17, CI = -0.14 – 0.48), and developed ($\hat{w}$ = 0.00, CI = 0.00 – 0.00). Perkins County individuals (n = 34) did not select for any specific habitat types, and avoided other cropland ($\hat{w}$ = 0.52, CI = 0.19 – 0.86) and developed ($\hat{w}$ = 0.20, CI = -0.32 – 0.73).

Selection ratios for several habitat categories differed among counties during winter 2014 – 2015 (Table 3-7). Forested differed among counties ($F_{2, 81}$ = 4.82, P = 0.01, n = 84) with Grant ($\bar{x}$ = 4.53) greater than Perkins ($\bar{x}$ = 1.35, P = 0.007). Corn differed among counties ($F_{2, 81}$ = 3.52, P = 0.03, n = 84) with Grant ($\bar{x}$ = 0.93) greater than Dunn ($\bar{x}$ = 0.16, P = 0.03). Cereal grains differed among counties ($F_{2, 81}$ = 2.91, P = 0.06, n = 84) with Perkins ($\bar{x}$ = 0.73) greater than Grant ($\bar{x}$ = 0.35, P = 0.05). Fallow differed among counties ($F_{2, 81}$ = 3.10, P = 0.05, n = 84) with Grant ($\bar{x}$ = 0.22) greater than Perkins ($\bar{x}$ = 0.00, P = 0.08). We found no other differences in design III resource selection among counties during winter 2014 – 2015 ($P \geq 0.15$).

Proportions of available habitats varied among counties at the home range level during winter 2014 -2015 (Table 3-8). Available grass/pasture varied among counties ($F_{2, 81}$ = 14.57, P < 0.001, n = 84) with both Grant ($\bar{x}$ = 58.92, P < 0.001) and Perkins ($\bar{x}$ =62.52, P < 0.001) greater than Dunn ($\bar{x}$ =36.94). Available forested varied among counties ($F_{2, 81}$ = 14.48, P < 0.001, n = 84) with Dunn ($\bar{x}$ = 6.62) greater than both Grant ($\bar{x}$ = 2.52, P < 0.001) and Perkins ($\bar{x}$ = 1.81, P < 0.001). Available hay/alfalfa varied among counties ($F_{2, 81}$ = 2.36, P = 0.10, n = 84) with Dunn ($\bar{x}$ = 9.59) greater than Perkins ($\bar{x}$ = 6.18, P = 0.08). Available sunflowers varied among counties ($F_{2, 81}$ = 7.07, P = 0.001, n = 84) with Dunn ($\bar{x}$ = 14.82) greater than both Grant ($\bar{x}$ = 2.84, P = 0.02) and Perkins ($\bar{x}$ = 1.64, P = 0.002). Available corn varied among counties ($F_{2, 81}$ = 6.52, P = 0.002, n = 84) with both Grant ($\bar{x}$ = 4.51, P = 0.08) and Perkins ($\bar{x}$ = 5.85, P = 0.002) greater than Dunn ($\bar{x}$ = 1.21). Available cereal grains varied among counties ($F_{2, 81}$ = 2.76, P = 0.07, n = 84) with Dunn ($\bar{x}$ = 22.14) greater than Perkins ($\bar{x}$ = 13.63, P = 0.06). Available fallow varied among counties ($F_{2, 81}$ = 8.94, P < 0.001, n = 84) with both Dunn ($\bar{x}$ = 3.38, P < 0.001) and Grant ($\bar{x}$ = 2.07, P = 0.06) greater than Perkins ($\bar{x}$ = 0.00). Available other cropland varied among counties ($F_{2, 81}$ = 3.32, P = 0.04, n = 84) with Perkins ($\bar{x}$ = 5.04) greater than Dunn ($\bar{x}$ = 1.50, P = 0.06). Available developed varied among counties ($F_{2, 81}$ = 9.32, P < 0.001, n = 84) with Dunn ($\bar{x}$ = 1.36) greater than both Grant ($\bar{x}$ = 0.45, P < 0.001) and Perkins ($\bar{x}$ = 0.69, P = 0.004). We found no other differences in available habitats among counties during winter 2014 – 2015 (P = 0.21).

Resource selection varied among counties during summer 2015 (Figure 3-8). Deer in Dunn County (n = 30) selected for forested ($\hat{w}$ = 2.06, CI = 1.54 – 2.59) and sunflowers ($\hat{w}$ = 1.65, CI = 1.20 – 2.10), but avoided cereal grains ($\hat{w}$ = 0.58, CI = 0.41 – 0.75) and developed ($\hat{w}$ = 0.20, CI = -0.02 – 0.42). Grant County deer (n = 30) selected for forested ($\hat{w}$ = 4.58, CI = 3.28 – 5.88) and wetlands ($\hat{w}$ = 1.56, CI = 1.15 – 1.98), but avoided grass/pasture ($\hat{w}$ = 0.78, CI = 0.68 – 0.87), cereal grains ($\hat{w}$ = 0.72, CI = 0.59 – 0.85), hay/alfalfa ($\hat{w}$ = 0.60, CI = 0.36 – 0.84), and other cropland ($\hat{w}$ = 0.46, CI = 0.13 – 0.78). Deer in Perkins County (n = 32) only selected for forested ($\hat{w}$ = 1.79, CI = 1.31 – 2.27). There is evidence for avoidance of developed ($\hat{w}$ = 0.42, CI = -0.41 – 1.25) in Perkins County as well.

Selection ratios for several habitat categories differed among counties during summer 2015 (Table 3-9). Grass/pasture varied among counties ($F_{2, 89}$ = 5.86, P = 0.004, n = 92) with both Dunn ($\bar{x}$ = 1.01, P = 0.003) and Perkins ($\bar{x}$ = 0.92, P = 0.08) greater than Grant ($\bar{x}$ = 0.77). Forested varied among counties ($F_{2, 89}$ = 21.3, P < 0.001, n = 92) with Grant ($\bar{x}$ = 6.11) greater than both Dunn ($\bar{x}$ = 2.19, P < 0.001) and Perkins ($\bar{x}$ = 1.85, P < 0.001). Wetlands varied among counties ($F_{2, 89}$ = 4.43, P = 0.01, n = 92) with Grant ($\bar{x}$ = 1.85) greater than Perkins ($\bar{x}$ = 0.89, P = 0.01). Hay/alfalfa varied among counties ($F_{2, 89}$ = 2.45, P = 0.09, n = 92) with Perkins ($\bar{x}$ = 0.79) greater than Grant ($\bar{x}$ = 0.36, P = 0.10). Corn differed among counties ($F_{2, 89}$ = 6.13, P = 0.003, n = 92) with Grant ($\bar{x}$ = 1.17) greater than both Dunn ($\bar{x}$ = 0.26, P = 0.009) and Perkins ($\bar{x}$ = 0.26, P = 0.008). Cereal grains differed among counties ($F_{2, 89}$ = 6.63, P = 0.002, n = 92) with Perkins ($\bar{x}$ = 0.83) greater than both Dunn ($\bar{x}$ = 0.43, P = 0.002) and Grant ($\bar{x}$ = 0.57, P = 0.06). Other cropland differed among counties ($F_{2, 89}$ = 2.77, P = 0.07, n = 92) with Perkins ($\bar{x}$ = 0.48) greater than Grant ($\bar{x}$ = 0.10, P = 0.10). We found no other differences in design III resource selection among counties during summer 2015 ($P \geq 0.22$).

Proportions of available habitats varied among counties at the home range level during summer 2015 (Table 3-10). Available grass/pasture varied among counties ($F_{2, 89}$ = 2.78, P = 0.07, n = 84) with Perkins ($\bar{x}$ = 50.20) greater than Dunn ($\bar{x}$ = 38.46, P = 0.06). Available forested varied among counties ($F_{2, 89}$ = 6.22, P = 0.003, n = 84) with Dunn ($\bar{x}$ = 6.48) greater than both Grant ($\bar{x}$ = 3.93, P = 0.05) and Perkins ($\bar{x}$ = 2.86, P = 0.002). Available wetlands varied among counties ($F_{2, 89}$ = 2.93, P = 0.06, n = 84) with Dunn ($\bar{x}$ = 6.88) greater than Perkins ($\bar{x}$ = 3.85, P = 0.05). Available fallow varied among counties ($F_{2, 89}$ = 8.40, $P < 0.001$, n = 84) with Grant ($\bar{x}$ = 3.39) greater than both Dunn ($\bar{x}$ = 0.31, $P < 0.001$) and Perkins ($\bar{x}$ = 0.96, P = 0.01). Available developed varied among counties ($F_{2, 89}$ = 13.38, $P < 0.001$, n = 84) with Dunn ($\bar{x}$ = 2.44) greater than both Grant ($\bar{x}$ = 0.61, $P < 0.001$) and Perkins ($\bar{x}$ = 0.66, $P < 0.001$). We found no other differences in available habitats among counties during summer 2015 ($P \geq 0.12$).

DISCUSSION

Despite available habitat differing among counties, resource selection was generally comparable from the population to home range level in all three counties of our study. At the population level, deer commonly selected areas with agricultural crops (i.e., corn and sunflowers), wetlands, and forests in the summer, and areas with agricultural crops and forests in the winter. At the home range level, deer generally selected forests and wetlands in the summer as well as forests in the winter. Overall, our results are consistent with other studies in the region (Grovenburg et al. 2010, 2011, Robling 2011), and suggest that areas providing adequate forage and thermal/escape cover are of primary importance for deer.

Although our results did not support our hypothesis that deer in Dunn County would have the lowest selection ratios for developed areas compared to Grant and Perkins counties due to oil and gas development, there was evidence that deer in Dunn County avoided developed areas. Overall, Perkins County had the lowest selection ratios for developed for both design II and III; however, Perkins County had the lowest amount of developed area available on the landscape. In addition, we included roads in our development category, which may have made it difficult to differentiate roads from oil and gas well pads in Dunn County. However, our results did show that deer in Dunn County avoided developed areas at the population level in summer 2015 and at the home range level in both summer 2014 and 2015.

Furthermore, the wide confidence intervals surrounding the developed category for deer at the home range level in Dunn County during winter 2014 – 2015 suggest that the level of selection varied highly for individual deer. Sawyer et al. (2017) found that mule deer aversion to well pads decreased with winter severity; therefore, even though deer avoided development in the summer, severe winters forced deer to use habitat near well pads that they otherwise would have avoided. We suggest that generally, deer in Dunn County avoided development; however, some deer were forced to use habitat closer to developed areas during harsh winter conditions.

Deer select areas that include combinations of habitats that give them the best chance of reproductive success (Fretwell 1972). At the population level, deer generally selected for agriculture as well as thermal and escape cover. Our findings were consistent with Grovenburg et al. (2011) who found that white-tailed deer selected corn and Robling (2011) who found that deer used wetlands and trees the most regardless of season. Although beyond the scope of the project, quality of grassland habitat for fawn bedding sites can be highly variable due to precipitation and grazing pressure (Grovenburg 2011). Huegel et al. (1986) in south central Iowa reported that tall grass at bedding sites was less than random sites and 77% of the bedding sites were in forest cover; whereas sites in the Dakotas suggest that greater vertical grassland vegetation height to be the driver for fawn bedding site selection and survival (Uresk et al. 1999, Grovenburg et al. 2012, Schaffer et al. 2014, Sternhagen 2015). Variation in grassland vegetation for fawn bedding sites may, in turn, influence adult female habitat use. Deer consistently selected wetlands, sunflowers, and forested areas in Dunn and Grant counties. Perkins County varied slightly in selection of species of crops as well as for forested areas. While Dunn and Grant had relatively similar landscapes, Perkins County had the lowest percentage of cropland and forested areas available, as well as the highest percentage of grasslands. As a consequence, variation in landscape configuration may have affected resource selection among counties at the population level.

At the home range level during winter, forested areas were most important for deer in every county, and during summer, deer generally selected forested and wetland areas as well as to a lesser extent, crops such as corn and sunflowers. Hobbs and Hanley (1990) found that resource use is dependent on the quantity and quality of resource availability. We believe that differences in the amount of cropland between years, in addition to the amount of forested and wetland areas among counties affected the resource selection strategies for deer in our study. Forests and wetlands were some of the most limited habitats available. Low deer densities in our study areas allowed deer to use this finite thermal and escape cover. However, if densities increase, deer populations may be limited by the availability of escape and thermal cover (Walter et al. 2009).

MANAGEMENT IMPLICATIONS

Our results suggest that thermal and escape cover as well as high quality forage are essential to deer. Maximizing deer abundance on the Northern Great Plains depends upon ensuring that there are suitable forested areas and wetlands for cover, in addition to agricultural crops available to deer for winter forage. Managers should encourage planting tree rows and shelterbelts in addition to food plots, and encourage farmers to leave strips of nearby unharvested crops such as corn or sunflowers for wildlife use during harsh winters. Leaving strips of unharvested crops may reduce wildlife depredation on hay intended for feeding cattle during the winter as well. In addition, reducing depredation in hay yards is important for decreasing the risk of the spread of disease. When deer congregate at feeding areas, nose to nose contact increases the risk of transmitting diseases such as Chronic Wasting Disease (CWD). This is especially important in Grant County, where CWD has been documented. It is also important to minimize the amount of habitat lost, especially with regard to development such as oil and gas in Dunn County. When well pads are present, deer may be displaced from potentially desirable habitat (Sawyer et. al 2006), which in turn can reduce overall deer abundance (Sawyer et al. 2017). Placement of well pads away from established forested areas and wetlands may minimize the potential for long-term displacement impacts on deer.

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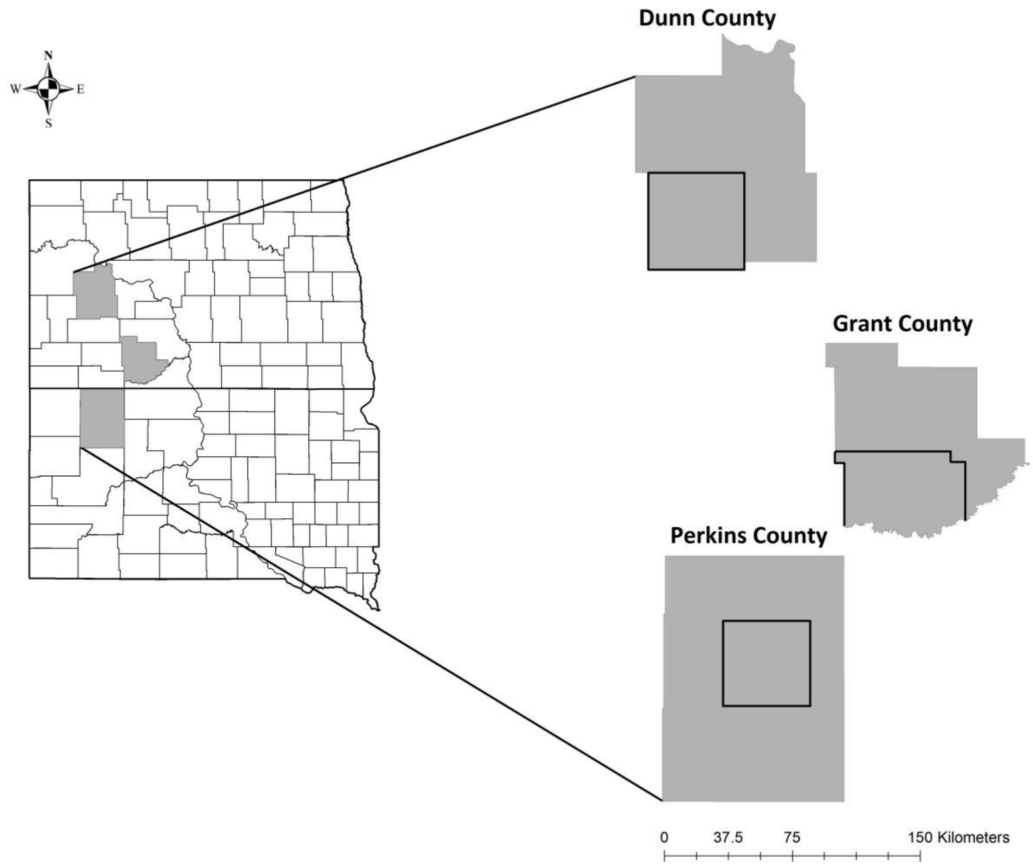

Figure 3-1. Study areas for female white-tailed deer (*Odocoileus virginianus*) located in Grant and Dunn Counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 and 2015.

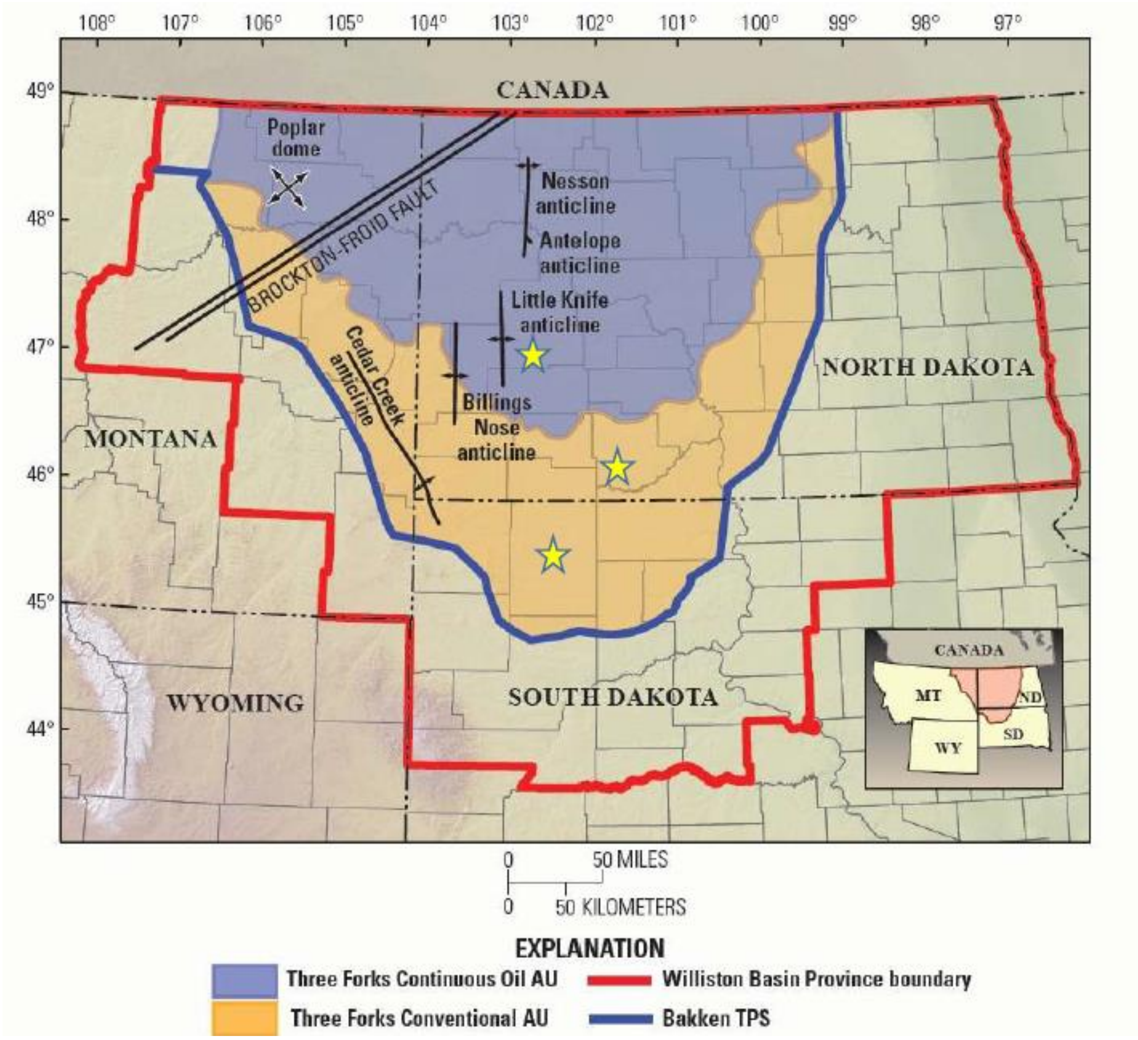

Figure 3-2. Bakken-Three Forks Formations in the Williston Basin in the Northern Great Plains (U.S. Geological Survey 2013). Yellow stars indicate study areas.

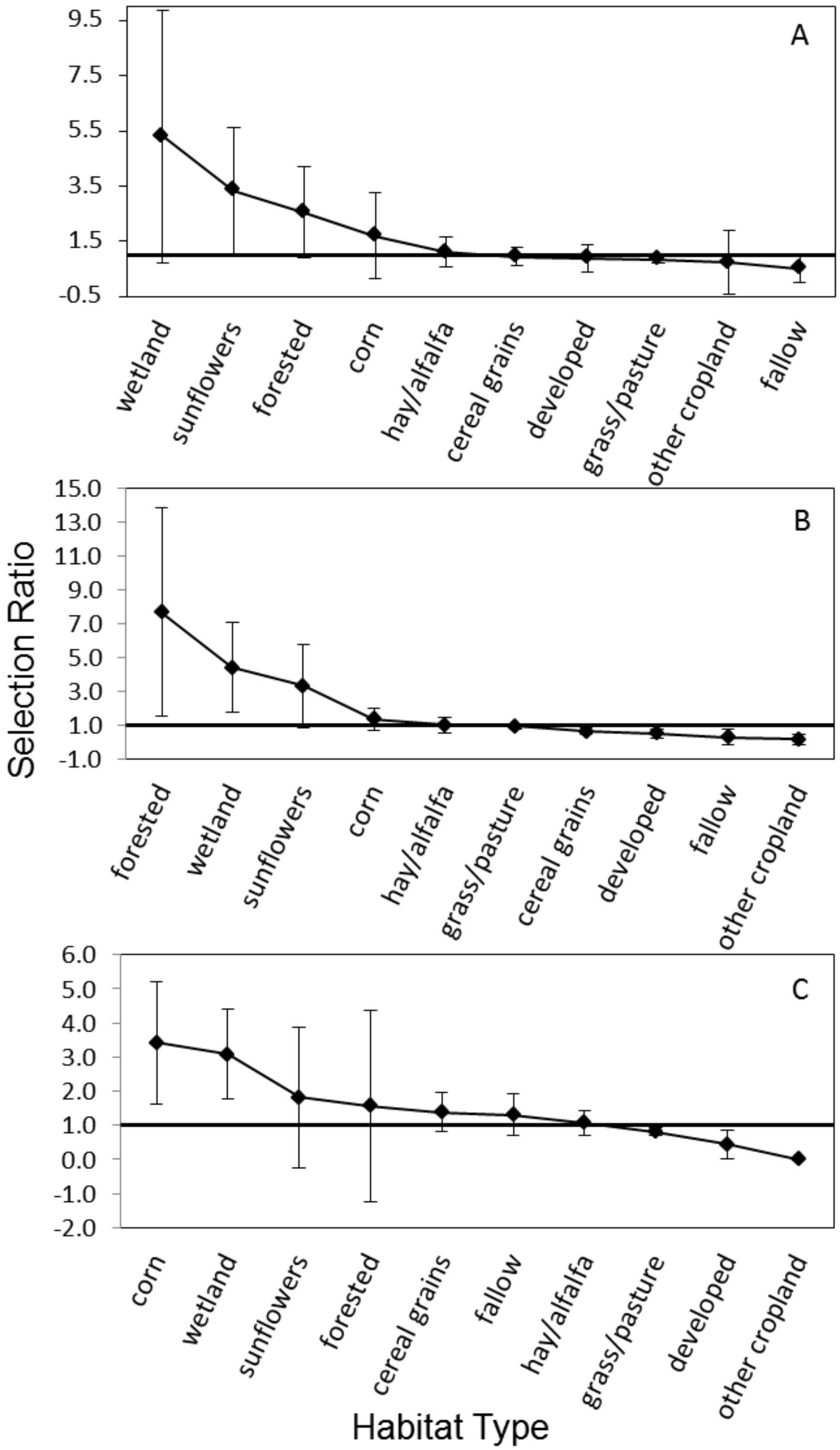

Figure 3-3. Design II selection ratios (ŵ) for female white-tailed deer (*Odocoileus virginianus*) in (A) Dunn and (B) Grant counties, North Dakota and (C) Perkins County, South Dakota during summer 2014. Confidence intervals not overlapping 1 indicate either selection for (>1) or avoidance of (<1) habitat types.

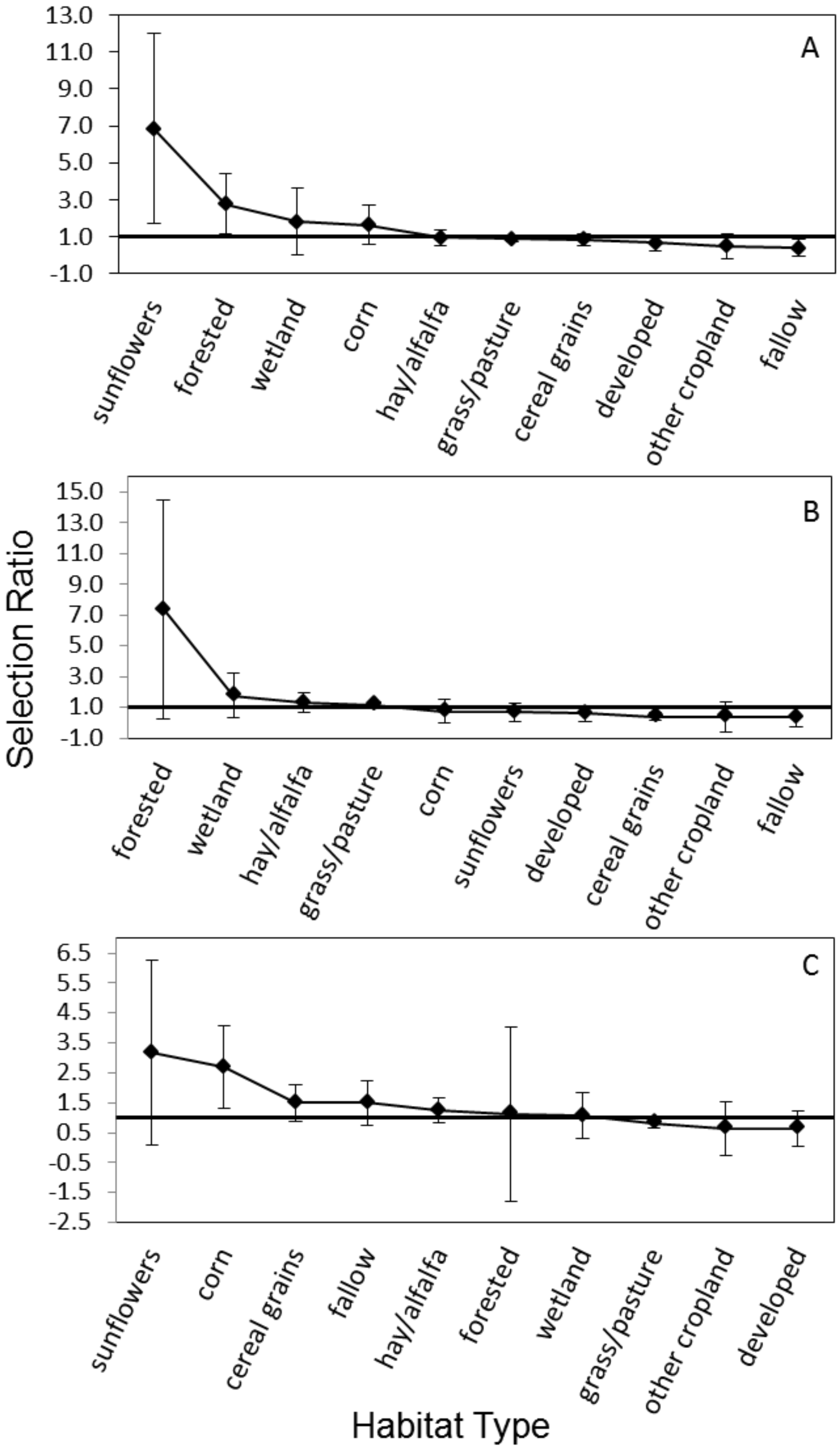

Figure 3-4. Design II selection ratios (ŵ) for female white-tailed deer (*Odocoileus virginianus*) in (A) Dunn and (B) Grant counties, North Dakota and (C) Perkins County, South Dakota during winter 2014 – 2015. Confidence intervals not overlapping 1 indicate either selection for (>1) or avoidance of (<1) habitat types.

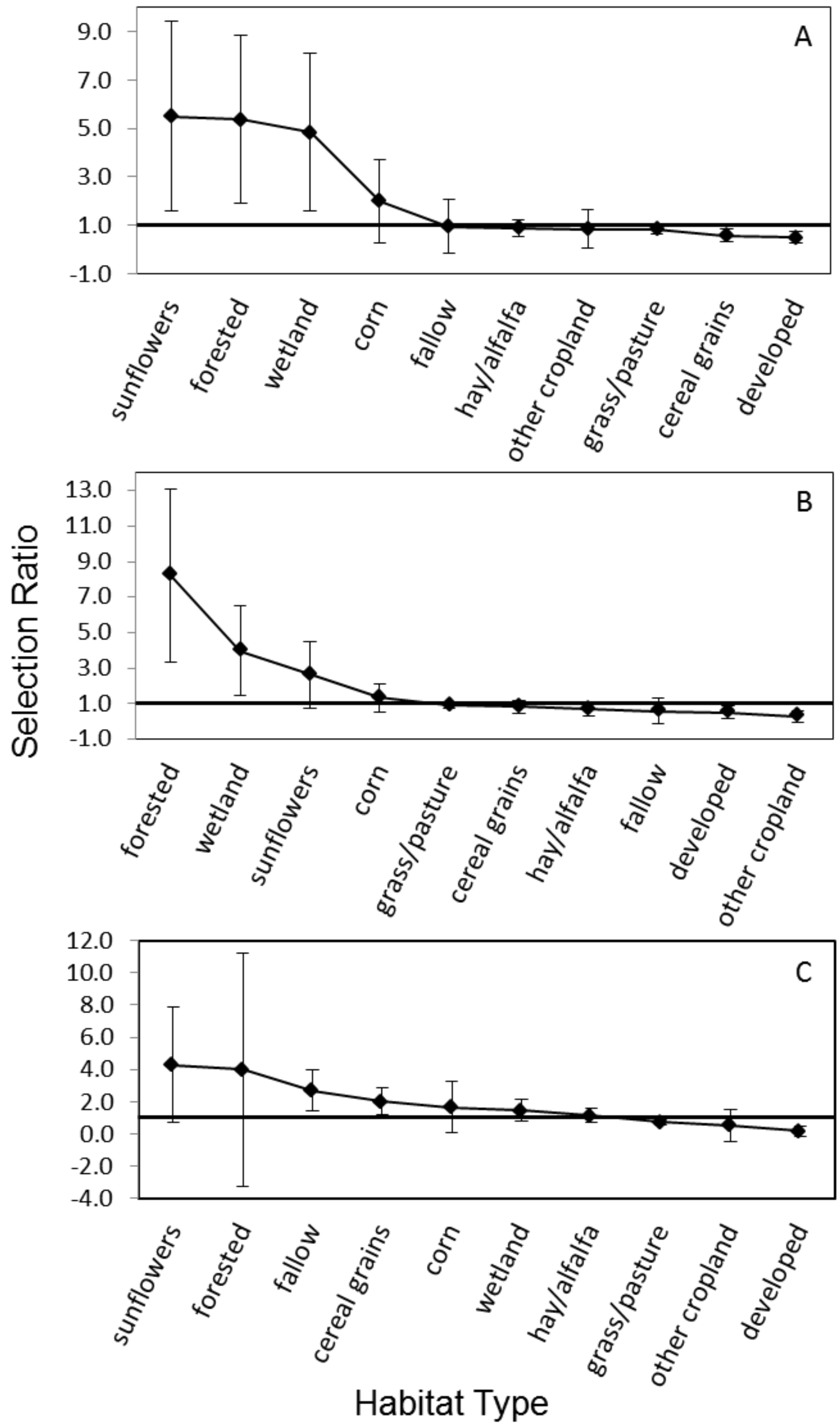

Figure 3-5. Design II selection ratios (ŵ) for female white-tailed deer (*Odocoileus virginianus*) in (A) Dunn and (B) Grant counties, North Dakota and (C) Perkins County, South Dakota during summer 2015. Confidence intervals not overlapping 1 indicate either selection for (>1) or avoidance of (<1) habitat types.

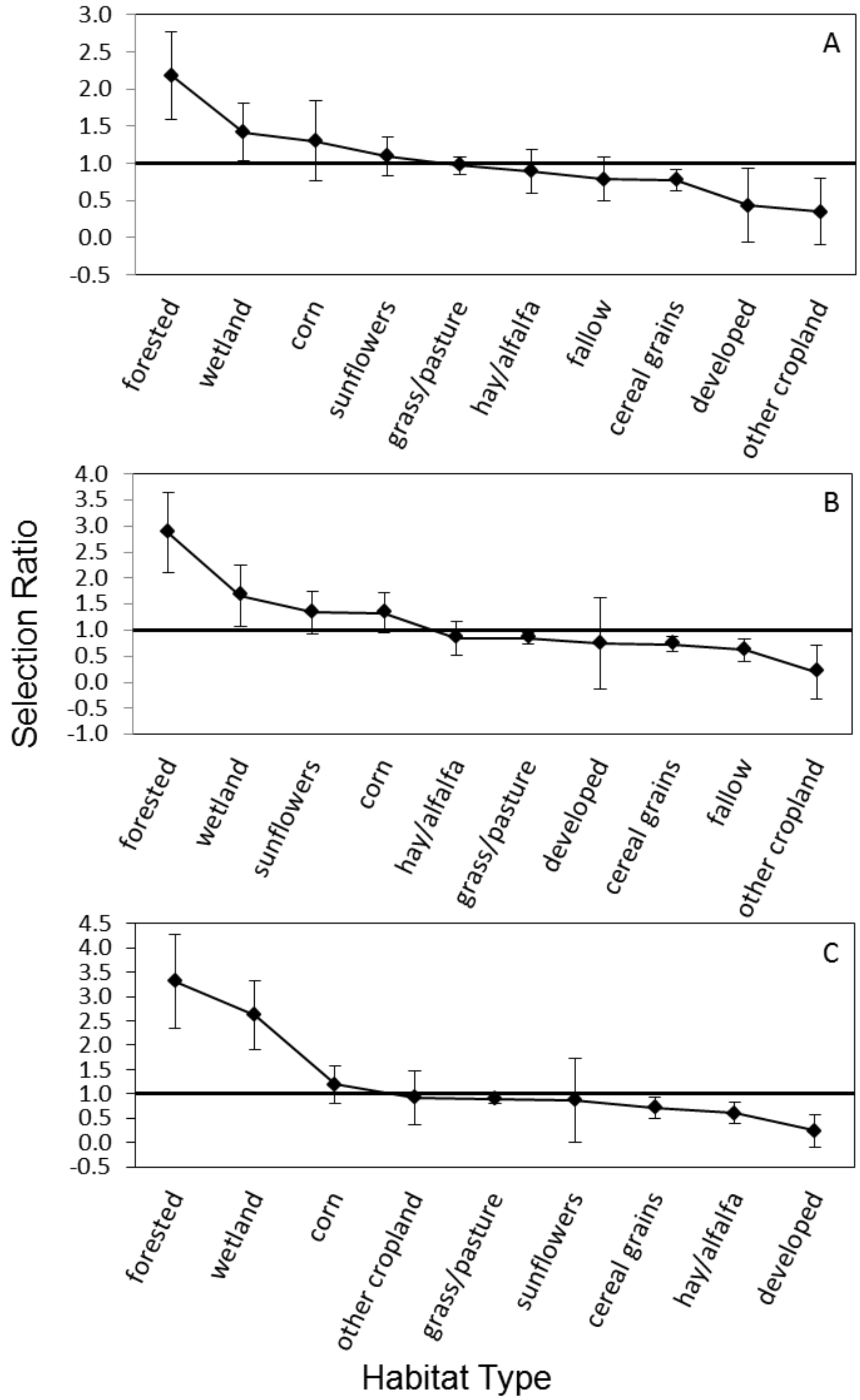

Figure 3-6. Design III selection ratios (ŵ) for female white-tailed deer (*Odocoileus virginianus*) in (A) Dunn and (B) Grant counties, North Dakota and (C) Perkins County, South Dakota during summer 2014. Confidence intervals not overlapping 1 indicate either selection for (>1) or avoidance of (<1) habitat types.

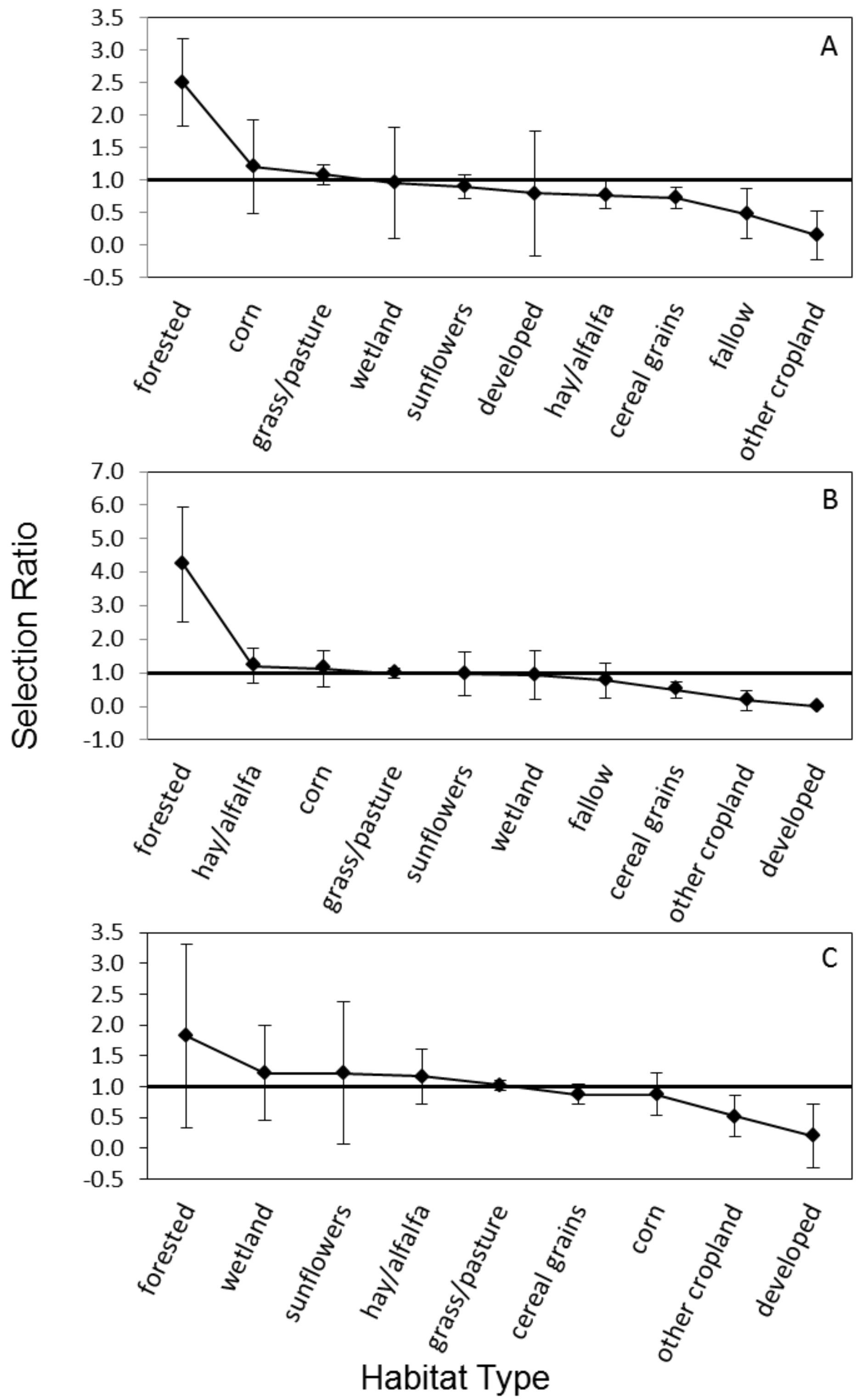

Figure 3-7. Design III selection ratios (ŵ) for female white-tailed deer (*Odocoileus virginianus*) in (A) Dunn and (B) Grant counties, North Dakota and (C) Perkins County, South Dakota during winter 2014 – 2015. Confidence intervals not overlapping 1 indicate either selection for (>1) or avoidance of (<1) habitat types.

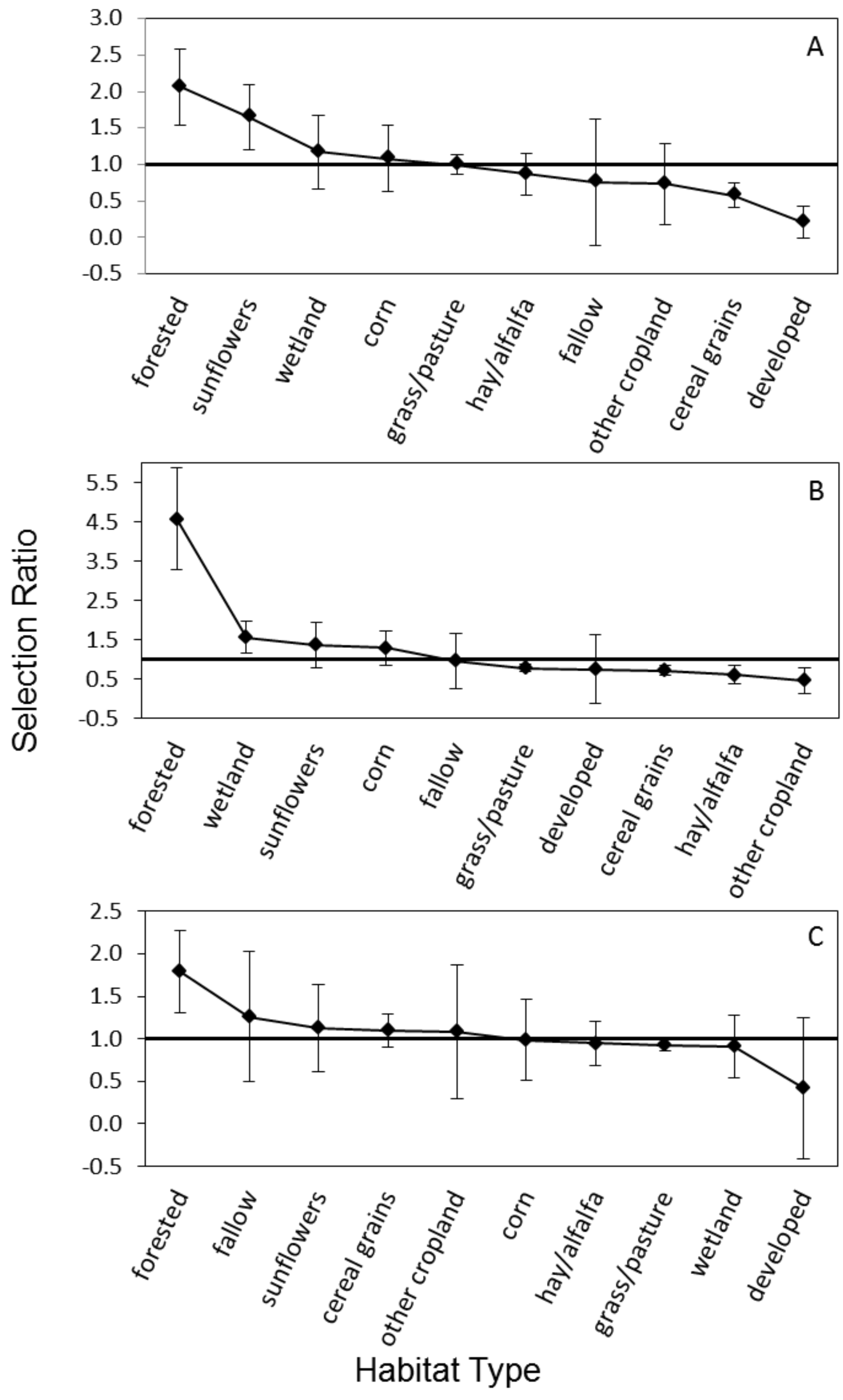

Figure 3-8. Design III selection ratios (ŵ) for female white-tailed deer (*Odocoileus virginianus*) in (A) Dunn and (B) Grant counties, North Dakota and (C) Perkins County, South Dakota during summer 2015. Confidence intervals not overlapping 1 indicate either selection for (>1) or avoidance of (<1) habitat types.

Table 3-1. Population level land cover in Grant and Dunn counties, North Dakota, USA and Perkins County, South Dakota, USA during 2014 and 2015 (USDA 2014, 2015).

County	Cropland (%)	Grassland (%)	Forested (%)	Wetland (%)	Developed (%)	Total (%)
[a]Dunn	41.29	53.97	1.00	0.65	3.08	100
[a]Grant	37.95	57.35	0.30	1.15	3.25	100
[a]Perkins	28.29	68.41	0.09	1.93	1.28	100
[b]Dunn	43.22	51.37	1.61	0.68	3.12	100
[b]Grant	40.70	54.31	0.36	1.35	3.27	100
[b]Perkins	26.14	70.14	0.20	2.04	1.48	100

[a]2014
[b]2015

Table 3-2. Design II average selection ratios ($\hat{w}$) by county for white-tailed deer in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota during summer 2014. Differences among counties are indicated by letters following $\hat{w}$'s.

Habitat Type	Dunn $\hat{w}$	Grant $\hat{w}$	Perkins $\hat{w}$
grass/pasture	0.85a	0.94a	0.82a
forested	2.80a	9.05b	1.48a
wetland	5.77a	4.39a	3.19a
hay/alfalfa	1.10a	0.98a	1.06a
sunflowers	3.25a	2.91a	1.76a
corn	1.62a	1.42a	3.35b
cereal grains	0.92ab	0.62a	1.34b
fallow	0.55a	0.29a	1.29b
other cropland	0.74a	0.17ab	0.00b
developed	0.89a	0.52a	0.45a

Table 3-3. Design II average selection ratios (ŵ) by county for white-tailed deer in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota during winter 2014 – 2015. Differences among counties are indicated by letters following ŵ's.

Habitat Type	Dunn ŵ	Grant ŵ	Perkins ŵ
grass/pasture	0.87a	1.14b	0.81a
forested	2.28a	7.17b	1.15a
wetland	1.56a	1.65a	1.03a
hay/alfalfa	0.83a	1.44a	1.23a
sunflowers	7.00a	0.62b	2.94b
corn	1.65ab	0.69a	2.66b
cereal grains	0.89a	0.47a	1.48b
fallow	0.34a	0.31a	1.56b
other cropland	0.34a	0.37a	0.60a
developed	0.76a	0.70a	0.63a

Table 3-4. Design II average selection ratios (ŵ) by county for white-tailed deer in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota during summer 2015. Differences among counties are indicated by letters following ŵ's.

Habitat Type	Dunn ŵ	Grant ŵ	Perkins ŵ
grass/pasture	0.84ab	0.92a	0.72b
forested	5.39a	8.71a	4.16a
wetland	5.09a	4.28ab	1.45b
hay/alfalfa	0.91ab	0.68a	1.15b
sunflowers	5.40a	2.48a	4.22a
corn	1.97a	1.30a	1.60a
cereal grains	0.56a	0.83a	2.00b
fallow	1.10a	0.60a	2.68b
other cropland	0.79a	0.31a	0.50a
developed	0.51a	0.48a	0.17a

Table 3-5. Design III average selection ratios (ŵ) by county for white-tailed deer in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota during summer 2014. Differences among counties are indicated by letters following ŵ's.

Habitat Type	Dunn ŵ	Grant ŵ	Perkins ŵ
grass/pasture	0.93a	0.84a	0.92a
forested	2.34a	3.55ab	5.69b
wetland	1.34a	1.35a	2.75b
hay/alfalfa	0.62a	0.60a	0.38a
sunflowers	0.43a	0.60a	0.34a
corn	0.50a	1.03b	0.70ab
cereal grains	0.63ab	0.78a	0.51b
fallow	0.24ab	0.44a	0.00b
other cropland	0.06a	0.04a	0.57b
developed	0.34a	0.42a	0.25a

Table 3-6. Design III average available habitat by county for white-tailed deer in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota during summer 2014. Differences among counties are indicated by letters.

Habitat Type	Dunn	Grant	Perkins
grass/pasture	37.63a	41.65a	59.68b
forested	4.58a	4.11a	3.18a
wetland	6.23a	4.32ab	3.50b
hay/alfalfa	11.92a	13.04a	7.61a
sunflowers	6.70ab	7.76a	1.68b
corn	3.29a	6.29a	6.14a
cereal grains	24.97a	16.76b	14.52b
fallow	2.36ab	4.89a	0.00b
other cropland	0.67a	0.57a	2.62b
developed	1.64a	0.62b	1.06b

Table 3-7. Design III average selection ratios (ŵ) by county for white-tailed deer in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota during winter 2014 – 2015. Differences among counties are indicated by letters following ŵ's.

Habitat Type	Dunn ŵ	Grant ŵ	Perkins ŵ
grass/pasture	1.03a	0.96a	1.04a
Forested	2.72ab	4.53a	1.35b
Wetland	0.94a	1.06a	1.03a
hay/alfalfa	0.50a	0.98a	0.77a
sunflowers	0.47a	0.29a	0.27a
Corn	0.16a	0.93b	0.43ab
cereal grains	0.54ab	0.35a	0.73b
Fallow	0.18ab	0.22a	0.00b
other cropland	0.04a	0.02a	0.15a
developed	0.36a	0.00a	0.16a

Table 3-8. Design III average available habitat by county for white-tailed deer in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota during winter 2014 – 2015. Differences among counties are indicated by letters.

Habitat Type	Dunn	Grant	Perkins
grass/pasture	36.94a	58.92b	62.52b
forested	6.62a	2.52b	1.81b
wetland	2.44a	3.51a	2.64a
hay/alfalfa	9.59a	7.68ab	6.18b
sunflowers	14.82a	2.84b	1.64b
corn	1.21a	4.51b	5.85b
cereal grains	22.14a	16.02ab	13.63b
fallow	3.38a	2.07a	0.00b
other cropland	1.50a	1.49ab	5.04b
developed	1.36a	0.45b	0.69b

Table 3-9. Design III average selection ratios (ŵ) by county for white-tailed deer in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota during summer 2015. Differences among counties are indicated by letters following ŵ's.

Habitat Type	Dunn ŵ	Grant ŵ	Perkins ŵ
grass/pasture	1.01a	0.77b	0.92a
forested	2.19a	6.11b	1.85a
wetland	1.24ab	1.85a	0.89b
hay/alfalfa	0.72ab	0.36a	0.79b
sunflowers	0.72a	0.70a	0.35a
corn	0.26a	1.17b	0.26a
cereal grains	0.43a	0.57a	0.83b
fallow	0.11a	0.45a	0.58a
other cropland	0.13ab	0.10a	0.48b
developed	0.15a	0.34a	0.49a

Table 3-10. Design III average available habitat by county for white-tailed deer in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota during summer 2015. Differences among counties are indicated by letters.

Habitat Type	Dunn	Grant	Perkins
grass/pasture	38.46a	43.11ab	50.20b
forested	6.48a	3.93b	2.86b
wetland	6.88a	5.24ab	3.85b
hay/alfalfa	10.71a	9.31a	14.39a
sunflowers	8.24a	6.90a	4.39a
corn	3.50a	5.66a	2.68a
cereal grains	22.79a	19.22a	19.09a
fallow	0.31a	3.39b	0.96a
other cropland	0.93a	2.64a	0.92a
developed	2.44a	0.61b	0.66b

CHAPTER 4: MANAGEMENT IMPLICATIONS

Information regarding white-tailed deer home ranges, movements, and resource selection in response to energy development is extremely beneficial to the North Dakota Game and Fish Department and South Dakota Game Fish and Parks in order to best manage white-tailed deer in the region.

We found that deer in our study area with oil and gas development (Dunn County) avoided well pads. When well pads are present, deer may be displaced from potentially desirable habitat, which in turn can reduce overall deer abundance. In addition, fluctuations in home range size can affect deer densities, which may impact the way managers set harvest rates. Oil and gas activities such as drilling of wells and construction of new of well pads should be minimized during periods where high quality habitat is needed such as fawning season and winter. Newer technologies such as horizontal drilling would be beneficial because it would minimize habitat lost to well pads. Placement of well pads away from established forested areas and wetlands may minimize the potential for long-term displacement impacts on deer.

Managers should continue monitoring radio collared individuals to help determine if deer acclimate to oil and gas pads. Individuals with well pads within their home ranges provide important data regarding habitat that allows them to avoid human activity associated with well pads. Maintaining undeveloped, refuge habitat is important for deer, especially near well sites.

Our results regarding resource selection suggest that thermal and escape cover as well as high quality forage are essential to deer. Maximizing deer abundance on the Northern Great Plains depends upon ensuring that there are suitable forested areas and wetlands for cover, in addition to agricultural crops available to deer for winter forage. Managers should encourage planting tree rows and shelterbelts in addition to food plots, and encourage farmers to leave strips of nearby unharvested crops such as corn or sunflowers for wildlife use during harsh winters. Leaving strips of unharvested crops may reduce wildlife depredation on hay intended for feeding cattle during the winter as well. In addition, reducing depredation in hay yards is important for decreasing the risk of the spread of disease. When deer congregate at feeding areas, nose to nose contact increases the risk of transmitting diseases such as chronic wasting disease (CWD) which has been documented in Grant County.

Migration distance information is important for keeping track of the potential spread of CWD. The longest migration documented in our study was 26.3 km in Grant County. By means of the longest migration distance as a reference and the locations where CWD has been documented, the disease could potentially spread into an area 2,175 km^2 around the known sites.