EFFECT OF OIL AND GAS DEVELOPMENT ON SURVIVAL AND HEALTH 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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CONTENTS

CHAPTER 3: ENERGY DEVELOPMENT IMPACTS ON WHITE-TAILED DEER SURVIVAL IN THE DAKOTAS

CHAPTER 4: SEROLOGICAL SURVEY AND PATHOGEN EXPOSURE OF ADULT FEMALE WHITE-TAILED DEER IN THE WESTERN DAKOTAS

LIST OF FIGURES

CHAPTER 2

CHAPTER 3

CHAPTER 4

LIST OF TABLES

CHAPTER 2

CHAPTER 3

CHAPTER 4

APPENDIX A

APPENDIX B

ABSTRACT

EFFECT OF OIL AND GAS DEVELOPMENT ON SURVIVAL AND HEALTH OF WHITE-TAILED DEER IN THE WESTERN DAKOTAS

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Oil and gas development in North Dakota has resulted in the need for information regarding how increased activity has affected white-tailed deer (*Odocoileus virginianus*) populations. We evaluated white-tailed deer ecology in response to energy development and hypothesized that oil and gas development would negatively affect adult and neonate white-tailed deer due to increased vehicle traffic and human-related effects. We captured and radio-collared adult female and neonate white-tailed deer across three study areas: Dunn County, North Dakota, an area influenced by energy development, and Grant County, North Dakota, and Perkins County, South Dakota, areas not impacted by energy development at this time. We radio-collared 84 neonates and 150 adult females during 2014 and 73 neonates and 15 adult females during 2015. We observed 31 adult female and 44 neonate mortalities during the study. Predation was the greatest source of adult female (35%) and neonate mortality (61%). Intrinsic three- and six-month fawn survival models indicated capture type (six-months: 53%, SE = 0.07 and 74%, SE = 0.05, VIT and opportunistic six-month fawns, respectively) influenced survival. Extrinsic three- and six-month fawn survival models indicated that canopy cover at capture locations positively influenced fawn survival, whereas precipitation during 3-8 weeks of age negatively influenced fawn survival (six-months: 72%, SE = 0.04). Distance to nearest oil well did not influence survival ($\beta = -0.21$, SE = 0.56). We also estimated survival rates based on study area (Dunn, Grant, and Perkins counties) and season (Post-hunt, January-April; Pre-hunt, May-August; and Hunt, September-December). Dunn County displayed the highest annual survival rate (96%, SE=0.02) followed by Perkins (93%, SE = 0.03) and Grant (75%, SE = 0.06) counties. Seasonal survival was highest (100%) during Pre-hunt and Post-hunt periods in Dunn and Perkins counties and was lowest during the Post-hunt period in Grant County (87%). We analyzed 2014 and 2015 blood serum separately because all chemistry tests in Grant County differed ($p < 0.01$) between 2014 and 2015 except aspartate aminotransferase, blood urea nitrogen, and calcium. We found differences ($p < 0.05$) in creatinine kinase, globulin, glucose, lactate dehydrogenase, magnesium, sodium, and total protein values among study areas during 2014. Pathogens with the highest antibody prevalence included West Nile Virus (85%), epizootic hemorrhagic disease (48%), and malignant catarrhal fever (32%). We speculate that low sodium values and West Nile Virus may be contributing to low neonate survival rates in Grant County. Serum chemistry differences may be attributed to differences in forage quality and availability across study areas. Our results indicated that oil and natural gas development did not negatively affect white-tailed deer survival and health. Other density-dependent factors likely explained differences in survival across study areas; nevertheless, further monitoring is needed to assess long-term responses of white-tailed deer to energy development.

CHAPTER 1: INTRODUCTION

White-tailed deer (*Odocoileus virginianus*) are an adaptable species that occupy several habitat types and are abundant across North America (Heffelfinger 2011). However, white-tailed deer abundance is generally limited by thermal cover and food resources (VerCauteren and Hygnstrom 2011). Density of white-tailed deer in the Northern Great Plains is low (<6 deer/km^2; Fulbright and Ortega-S 2013), but increased agricultural production has attracted and retained deer in the region (Heffelfinger 2011). High-quality and abundant foods in agricultural lands also has increased deer reproductive capacity and survival during severe winters (Nixon et al. 1991, Heffelfinger 2011).

Oil and gas development has increased in western North Dakota since the 1950s when the first oil well was drilled near Williston (Bluemle 2001). 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). High production levels ranked North Dakota second and thirteenth in the nation for crude oil and natural gas production, respectively, in 2014 (U. S. Department of Energy 2014). South Dakota produced over 1.8 million barrels of oil from nearly 180 wells in 2013 (South Dakota Department of Environment and Natural Resources 2016). Harding County, South Dakota, holds a majority of the active wells in the state, but the surrounding area may be exploited in the future.

Negative impacts of oil and natural gas development on ungulate behavior, movements, and habitat use have been well documented (Hebblewhite 2008, Riley et al. 2012). For example, pronghorn (*Antilocapra americana*) abundance in North Dakota was negatively impacted by increases in road and oil well density (Christie et al. 2015). Mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) have been documented shifting habitat use to areas away from energy development (Powell 2003, Sawyer et al. 2006), and caribou (*Rangifer tarandus*) have shown avoidance of energy development areas (Dyer et al. 2001). Although increased road abundance related to energy development does not prevent white-tailed deer movements, it can significantly increase mortality risk in high traffic areas (Stewart et al. 2011). Baseline information regarding white-tailed deer ecology in the western portions of North and South Dakota is unknown at this time, and potential impacts of oil and natural gas development on white-tailed deer have not been documented. Consequently, North Dakota Game and Fish Department uses published mule deer responses to oil and natural gas development as a surrogate for potential impacts on white-tailed deer, which assumes that both species respond similarly (Dyke et al. 2011).

Baseline survival and health data is needed for accurate white-tailed deer management in North and South Dakota. Therefore, our objectives were to: 1) assess the potential impacts of oil and gas development on white-tailed deer ecology, 2) estimate survival rates and cause-specific mortality for female and neonate white-tailed deer, and 3) document nutritional indices and pathogen exposure rates for female white-tailed deer. We hypothesized that oil and natural gas development would negatively impact white-tailed deer survival and health because of increased noise disturbance (Stankowich 2008) and increased vehicle collisions due to increased traffic (Johnson 1980, Frair 2005). We predicted that white-tailed deer in areas with oil and natural gas development would have lower survival rates and overall health compared to white-tailed deer inhabiting areas without oil and natural gas development.

LITERATURE CITED

Bluemle, J. P. 2001. The 50th anniversary of the discovery of oil in North Dakota. North Dakota Geological Survey.<https://www.dmr.nd.gov/ndgs/documents/Publication_List/pdf/MiscSeries/MS-89.pdf> Accessed 14 July 2016.

Christie, K. S., W. F. Jensen, J. H. Schmidt, and M.S. Boyce. 2015. Long-term changes in pronghorn abundance index linked to climate and oil development in North Dakota. Biological Conservation 192:445-453.

Department of Mineral Resources [DMR] Oil and Gas Division. 2016. DMR Homepage. <https://www.dmr.nd.gov/> Accessed 14 June 2016.

Dyer, S., J. O'Neill, S. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. Journal of Wildlife Management 65: 531-542.

Dyke, S., D. Fryda, D. Kleyer, J. Williams, B. Hosek, W. Jensen, S. Johnson, A. Robinson, F. Ryckman, B. Stillings, M. Szymanski, S. Tucker, and B. Wiedmann. 2011. Potential impacts of oil and gas development on select North Dakota natural resources; a report to the director. North Dakota Game and Fish Department.

Frair, J. L. 2005. Survival and movement behaviour of resident and translocated wapiti (*Cervus elaphus*): implications for their management in west-central Alberta, Canada. University of Alberta. Edmonton, Alberta, Canada.

Fulbright, T. E. and J. A. Ortega-S. 2013. White-tailed deer habitat: ecology and management on rangelands. 2nd edition. Texas A & M University Press, College Station, Texas, USA.

Hebblewhite, M. 2008. A literature review of the effects of energy development on ungulates: Implications for central and eastern Montana. Report prepared for Montana Department of Fish, Wildlife and Parks, Miles City, MT.

Heffelfinger, J. R. 2011. Taxonomy, evolutionary history, and distribution. Pages 3-39 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Johnson, B. 1980. Response of elk during calving to oil gas drilling activity in Snider Basin, Wyoming, Wyoming Game and Fish Department.

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

Powell, J. 2003. Distribution, habitat use patterns, and elk response to human disturbance in the Jack Marrow Hills, Wyoming. M.S. Thesis, University of Wyoming, Laramie, USA.

Riley, T. R., E. M. Bayne, B. C. Dale, D. E. Nauugle, J. A. Rodgers, and S. C. Torbit. 2012. Impacts of crude oil and natural gas developments on wildlife and wildlife habitat in the Rocky Mountain region. Technical Review prepared for The Wildlife Society, Bethesda, MD.

Sawyer, H., R. Nielson, F. Lindzey, and L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. Journal of Wildlife Management 70:396-403.

South Dakota Department of Environment and Natural Resources [DENR]. 2016. DENR homepage. <http://denr.sd.gov>Accessed 14 June 2016.

Stankowich, T. 2008. Ungulate flight responses to human disturbance: a review and meta-analysis. Biological Conservation 141:2159-2173.

Stewart, K. M., R. T. Bowyer, and P. J. Weisberg. 2011. Spatial use of landscape. Pages 181-218 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

U. S. Department of Energy. 2014. U. S. Energy Information Administration, Rankings: Total Energy Consumed per Capita, 2014. Energy Information Administration Office, Washington, D. C., USA.

VerCauteren, K. C. and S. E. Hygnstrom. 2011. Managing white-tailed deer: Midwest North America. Pages 501-535 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

CHAPTER 2: SURVIVAL OF WHITE-TAILED DEER NEONATES IN THE WESTERN DAKOTAS

ABSTRACT Oil and natural gas development has expanded in recent decades and impacts on white-tailed deer (*Odocoileus virginianus*) survival and human-related mortality are unknown. Our objective was to assess three- and six-month survival rates for white-tailed deer fawns in western North Dakota and northwestern South Dakota and compare white-tailed deer fawn survival among control and treatment (i.e., oil and natural gas development) study areas. Areas included Dunn County, North Dakota, an area influenced by energy development and Grant County, North Dakota and Perkins County, South Dakota, areas not currently impacted by energy development. We captured 84 and 73 neonates during 2014 and 2015, respectively, across study areas. We used intrinsic and extrinsic models to estimate fawn survival. Intrinsic factors included age intervals, capture type, sex, birth mass, and capture age. Extrinsic models included study area, year, canopy cover (%) at capture location, distance to nearest oil well (km), water (km), and road (km), and precipitation during age intervals. The top intrinsic model was S(Capture) indicating that six-month survival of fawns captured from VITs (0.53, SE = 0.07, CI = 0.39-0.67) was lower than opportunistically captured fawns (0.74, SE = 0.05, CI = 0.63-0.82) at six months of age. The top extrinsic model was S(Canopy+Precip2) indicating fawn six-month survival (0.72, SE = 0.04, CI = 0.63-0.80) was positively influenced by canopy cover at capture sites and negatively influenced by precipitation during 3 to 8 weeks of age. The top extrinsic six-month survival model for fawns in Dunn County was S(.) indicating constant survival (0.74, SE = 0.07, CE = 0.58-0.85). Six-month fawn survival was highest in Perkins County (0.88, SE = 0.03, CI = 0.76-0.94)

during 2015 and lowest in Grant County (0.20, SE = 0.08, CE = 0.08-0.42) during 2014. Our results indicated there were no detectable negative impacts of oil and natural gas development on white-tailed deer fawn survival. Other density-dependent factors likely explained differences in survival across study areas; nevertheless, further monitoring is needed to determine long-term responses of white-tailed deer fawns to energy development.

INTRODUCTION

Several factors impact neonate survival and recruitment such as female body condition and predation. Females in better body condition are more likely to produce larger, healthier fawns with higher chances of survival than mothers in poor body condition (Carstensen et al. 2009, Duquette et al. 2015, Shallow et al. 2015). Heavier females produce heavier and potentially more reproductively successful offspring, which increases female fitness (Michel et al. 2015). Predation is generally the largest cause of mortality for white-tailed deer (*Odocoileus virginianus*) fawns in North America (Rohm et al. 2007, Grovenburg et al. 2011) and thus, decrease fawn recruitment (Kilgo et al. 2012, Jackson and Ditchkoff 2013). Several studies in the southeastern USA have indicated that coyote (*Canis latrans*) removal has increased fawn recruitment into the hunted population (McCoy et al. 2013, Conner et al. 2016).

White-tailed deer fawn habitat use and survival has been documented in western Minnesota (Brinkman et al. 2004) and eastern South Dakota (Grovenburg et al. 2011), but similar information has not been collected in the western Dakotas. Furthermore, increasing oil and natural gas development may influence habitat use and survival. Oil and natural gas development has been documented to cause avoidance in caribou

(*Rangifer tarandus*) during late winter and during the calving season (Dyer et al. 2001), disrupt pronghorn (*Antilocapra americana*) migrations (Sawyer et al. 2005, Beckmann et al. 2008), and cause mule deer (*Odocoileus hemionus*) to avoid areas near well pads (Sawyer et al. 2006). North Dakota Game and Fish Department uses reported mule deer responses to oil and natural gas development as a surrogate for potential impacts on white-tailed deer, which assumes response is equivalent for the two species (Dyke et al. 2011).

Researchers commonly use vaginal implant transmitters (VITs) to locate neonate ungulates and birth sites for studies involving survival and habitat use (Bowman and Jacobson et al. 1998, Johnstone-Yellin et al. 2006). Previous research investigated effectiveness of locating neonates and birth sites from females equipped with VITs and confirmed that VITs are effective for locating fawns within days after parturition and identifying fawning habitat (Bishop et al. 2006, Barbknecht et al. 2008, Swanson et al. 2008). Little information is available on how using VITs to capture fawns can influence estimated survival rates (Gilbert et al. 2014). Opportunistic captures could bias survival estimates because fawns could have died after birth before sampling, whereas using VITs to capture fawns allows for capture immediately after birth and detection of mortalities early in life.

Our objective was to assess the influence of oil and natural gas development on neonatal white-tailed deer ecology. We investigated survival rates and cause-specific mortality for white-tailed deer neonates in western North Dakota and northwestern South Dakota, USA. We hypothesized that oil and natural gas development would impact white-tailed deer neonate survival because fawns would be exposed to increased vehicle collisions (Johnson et al. 1980, Frair 2005) as a result of females with offspring displaying greater flight responses than adult groups (Stankowich 2008). We further hypothesized that fawns would display higher mortality in energy development due to their lack of experience with humans similar to predator-prey naivety (Berger et al. 2001, McCormick and Holmes 2005, Smith et al. 2008, Sih et al. 2010). Therefore, we predicted that oil and natural gas development would negatively affect fawn survival.

STUDY AREA

We investigated neonate white-tailed deer survival rates and cause-specific mortality in Grant and Dunn counties, North Dakota and Perkins County, South Dakota (Figure 2-1) during 2014 and 2015. Counties were located in the Northwestern Great Plains Level III Ecoregion (Bryce et al. 1998) with each study area located in the Williston Basin Geological Formation (U. S. Geological Survey 2013, Figure 2-2).

In Dunn County, we focused deer capture in a 1,492 km^2 area in the southwestern portion of the county. Grasslands, cropland, and forested areas in Dunn County comprised 60, 20, and 9% of the land cover, respectively (Cropland Data Layer, U. S. Department of Agriculture 2015) and estimated minimum white-tailed deer density, based upon winter aerial surveys, was 1.0 deer/km^2 in 2011 (Stillings et al. 2012). Thirty-year mean annual precipitation in Dunn County was 41.4 cm and thirty-year mean monthly temperature ranged from -15.1ºC to 29.3ºC (North Dakota State Climate Office 2016).

In Grant County, we focused deer capture in a 1,865 km^2 area in the southwestern portion of the county. Grasslands, cropland, and forested areas in Grant County comprised 68, 26, and 1% of the land cover, respectively (Cropland Data Layer, U. S. Department of Agriculture 2015) and estimated minimum winter white-tailed deer density was 1.8 deer/km^2 in 2011 (Stillings et al. 2012). Seven (1 white-tailed deer, 6 mule deer) deer tested positive for chronic wasting disease (CWD) in Grant County since 2009 (D. M. Groves, North Dakota Game and Fish Department, personal communication). Thirty-year mean annual precipitation in Grant County was 41.2 cm and thirty-year mean monthly temperature ranged from -14.4^{o}C to 29.7^{o}C (North Dakota State Climate Office 2016).

In Perkins County, we focused deer capture in a 1,492 km^2 area in the central portion of the county. Grasslands, cropland, and forested areas in Perkins County comprised 86, 11, and 0.01% of the land cover, respectively (Cropland Data Layer, U. S. Department of Agriculture 2015). White-tailed deer density was estimated at 1.2 ± 0.04 deer/km^2 during 2015 (K. Robling, South Dakota Department of Game, Fish and Parks, personal communication). Thirty-year mean annual precipitation in Perkins County was 44.9 cm and mean thirty-year monthly temperature ranged from -12.1^{o}C to 30.3^{o}C (North Dakota State Climate Office 2016).

Grasslands in this region were dominated by native mixed grassland prairie species such as western wheatgrass (*Pascopyrum smithii*), needle and thread (*Hesperostipa comata*), green needle grass (*Nassella viridula*), little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*,), prairie junegrass (*Koeleria macrantha*), and reed canary grass (*Phalaris arundinacea*) (Sedivec et al. 2011). Introduced grasses included smooth brome (*Bromus inermis*), orchard grass (*Dactylis glomerata*), crested wheatgrass (*Agropyron sp.), timothy (*Phleum pratense*), and Kentucky bluegrass (*Poa pratensis*) (Sedivec et al. 2011). Primary harvested crops included corn (*Zea mays*), wheat (*Triticum aestivum*), sunflowers (*Helianthus annuus*), and alfalfa (*Medicago sativa*) (Sedivec et al. 2011). Other crops included flaxseed (*Linum usitatissimum*), canola (*Brassica* sp.), soybeans (*Glycine max*), barley (*Hordeum vulgare*), safflower (*Carthamus tinctorius*), oats (*Avena sativa*), and Sudan grass (*Sorghum bicolor,* spp. *drummondii*) (Sedivec et al. 2011).

Oil and natural gas development was prevalent in North Dakota. For example, 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). High production levels ranked North Dakota second and thirteenth in the nation for crude oil and natural gas production, respectively, in 2014 (U. S. Department of Energy 2014). Currently, there are about 1,800 active oil wells in Dunn County producing approximately 64 million barrels of oil and 35 MCF of natural gas each year (Department of Mineral Resources Oil and Gas Division 2016). Grant and Perkins counties capped and abandoned oil and natural gas wells by the 1980s due to low productivity (Department of Mineral Resources Oil and Gas Division 2016, South Dakota Department of Environment and Natural Resources 2016).

Recreational hunting season dates were similar across study areas and occurred from 4 September 2014 to 4 January 2015 and 4 September 2015 to 3 January 2016 in North Dakota. Recreational hunting occurred from 27 September 2014 to 15 January 2015 and 26 September 2015 to 15 January 2016 in South Dakota.

METHODS

We captured adult female (> 1.5-year-old) white-tailed deer via helicopter net guns (Native Range Capture Services, Elko, NV, USA, 2014) from 24 February to 2 March, 2014. Helicopter crew members hobbled, blindfolded, and fitted individuals with Very High Frequency (VHF) radio-collars and Vaginal Implant Transmitters (VIT; Advanced Telemetry Systems, Inc., Isanti, MN, USA). We implanted VITs in a subset of females to aid in determining fawning habitat in each study area. We captured additional adult female white-tailed deer in Grant County via helicopter net guns (Quicksilver Air Inc., Peyton, CO, USA, 2015) on 14 February 2015. Crews transported captured individuals below the helicopter in canvas transport bags to a processing site. We gave each individual 1 ml Banamine and 3 ml BO-SE (Selenium and Vitamin E, D. M. Grove, North Dakota Game and Fish Department, personal communication).

We searched for white-tailed deer neonates near expelled VITs, areas of known fawning habitat, and near females who showed postpartum behavior such as isolation or fleeing short distances when approached (Rohm et al. 2007, Grovenburg et al. 2010) and then captured neonates by hand or net. We restrained and blindfolded neonates upon capture, determined sex and general body condition, recorded body mass (kg), measured hoof growth (mm, Brinkman et al. 2004), and fitted individuals with a M4210 expandable breakaway radio-collar (Advanced Telemetry Systems, Isanti, MN, USA). We wore sterile rubber gloves, used no-scent spray, stored radio-collars and other equipment in natural vegetation, and kept handling time under five minutes when possible to reduce capture-related mortality. We only determined sex and radio-collared the neonate if individuals were wet from rain or afterbirth or were too large to fit in the weighing bag. All handling methods followed the American Society of Mammalogists guidelines for mammal care and use (Sikes et al. 2016) and were approved by the South Dakota State University Institutional Animal Care and Use Committee (Approval No. 13-091A).

We monitored fawns daily for mortality during the first 30 days using aerial telemetry, omnidirectional whip antennas, and handheld telemetry equipment. We monitored fawns for mortality 2-3 times a week after 30 days of the study. We investigated mortalities immediately after detecting a mortality signal and transported carcasses to the North Dakota Game and Fish Department Wildlife Laboratory in Bismarck, North Dakota, to confirm proximate cause of death. Natural causes of mortality were disease, predation, and unknown mortalities. We classified hunter harvest and vehicle collision mortalities (VCM) as human-related mortalities.

We summarized weekly fawn mortality using telemetry data (Grovenburg et al. 2014). We then estimated three-month (capture to 12 weeks; summer survival) survival rates using the Kaplan-Meier method (Kaplan and Meier 1958) for non-staggered entry and six-month (capture to 24 weeks; recruitment) survival rates using staggered entry (Pollock et al. 1989) via known fate models in Program MARK version 6.0 (White and Burnham 1999, Cooch and White 2016). Competing models were within 2 ΔAIC of the top model, and meaningful covariates had β-estimate 95% confidence intervals (CI) not including zero (Burnham and Anderson 2002).

We developed two candidate sets of models for three- and six-month survival. Candidate model set 1 estimated survival rates based on intrinsic factors influencing fawn survival. Intrinsic variables included age interval 1 (2-stage age interval: 0-2 weeks, 3+ weeks; Rohm et al. 2007, Grovenburg et al. 2011), age interval 2 (3-stage age interval: 0-2 weeks, 3-8 weeks, 9+ weeks; Nelson and Woolf 1987), capture type (VIT or opportunistic), sex, birth mass, and capture age. We estimated capture age for opportunistically caught fawns according to Haugen and Speake (1958). We back-calculated birth mass for individuals with unknown parturition dates using estimated age and assumed that fawns gain 0.215 kg per day (Verme et al. 1963). Wet or large fawns not weighed (n = 27) or measured (n = 33) during capture were assigned the average mass and hoof growth measures of fawns captured during the same week. We considered p-values $\leq$0.05 as significant and means were presented ± standard deviation. We only investigated age intervals in candidate model set 1 during the three-month time period. We also included the top model from candidate set 1 in candidate set 2 models to account for maximum variation in the data (Rohm et al. 2007, Grovenburg et al. 2011).

Candidate set 2 models estimated survival rates based on extrinsic factors influencing fawn survival (Rohm et al. 2007). Extrinsic variables included study area, year, distance from capture site to nearest road (km), water body (stream or stock pond; km), oil well (km, Dunn County), canopy cover (%) at fawn capture site, and precipitation during age intervals (0-2 weeks, 3-8 weeks, 9-12 weeks, 13-24 weeks). We removed the study area and year models from the candidate set as they held high model weight but were not biologically relevant.

We used camera scent-station surveys to estimate relative predator abundance in April and May 2015. Within our three study sites, we selected areas that contained radio-collared female home ranges and comprised 17 sections (2.6 km^2). We selected two survey areas in Dunn County that included one area with and one area without oil and natural gas development. We used ArcGIS 10.3.1 (Esri 2015) to plot 30 random points using 1000 m buffers in each area (Burr 2014). We then selected 15 of the 30 random points based on landowner permission and distance to edge habitat (Burr 2014). We defined edge habitat as areas where grassland, cropland, trees/shrubs, and fences intersected.

We placed Covert Extreme Red 40 (Covert Scouting Cameras, Inc., Lewisburg, KY, USA) infrared field cameras over 50 m from active roads near the closest habitat edge and faced them north or south to reduce sun glare (Burr 2014). We placed cameras approximately 0.5 m above the ground on a metal stake about 10 m from a scent lure and removed vegetation for a clear line of sight between the camera and scent lure (Burr 2014). We used two types of scent lures during the survey to prevent predator acclimation (Burr 2014). We used fatty acid scent tablets (Pocatello Supply Depot, Pocatello, ID, USA) for the first 11 days and then Caven's "Violator 7" predator lure (Minnesota Trapline Products, Pennock, MN, USA) for the next 11 days. We placed the second predator lure inside a hollow golf ball on a wooden dowel staked above ground to give an olfactory stimulus in addition to the scent (Burr 2014). We replaced scent lures every 4 – 5 days and after precipitation events to prevent dilution. We replaced memory cards and batteries on the twelfth day. Cameras took 3 pictures 3 seconds apart when triggered and could not be retriggered for 5 minutes (Burr 2014).

Cameras were deployed 1 – 22 April 2015 in Dunn and Grant counties. Cameras were deployed 25 April – 16 May 2015 in active oil development in Dunn County. Survey dates were later in active oil development because we had 15 cameras available for use in each study area. We deployed cameras from 1 April to 11 May 2015 in Perkins County due to landowner permission issues; only four cameras followed scent lure protocol due to the inability to access camera scent-stations on private property.

We reviewed pictures and identified meso-predators to species. We tallied the number of coyotes, red foxes (*Vulpes vulpes*), and badgers (*Taxidea taxus*), and used that information to calculate a scent-station index (SSI) for each of the four survey locations (Linhart and Knowlton 1975; Diefenbach et al. 1994). We calculated SSI using the following formula (Linhart and Knowlton 1975, Diefenbach et al. 1994).

$$\text{SSI} = \left[\frac{\text{\# predator visits}}{\text{\# station nights}}\right] * 1000$$

We calculated Deer Winter Severity Indices (DWSI, Brinkman et al. 2005) for the 2012-2013 and 2013-2014 winters. In North Dakota, one point was awarded each day the mean temperature was ≤-7° C. The index received an additional point for each day mean snow depth was ≥35.0 cm (Brinkman et al. 2005) from November to April. In South Dakota, we calculated the annual Winter Severity Index (WSI) from the sum of mean monthly WSI values from November to April using the following formula (K. Robling, South Dakota Department of Game, Fish and Parks, personal communication):

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

We regressed Perkins County DWSI against Grant County DWSI to adjust South Dakota estimates. Winters were considered mild when index values were below 50, moderate when index values were between 50 and 100, and severe when index values were above 100.

RESULTS

We captured and radio-collared 165 adult female white-tailed deer via helicopter net gun during 2014 and 2015 and placed VITs in 103 females. Seventy-six (74%) VITs were retained until parturition. We captured and radio-collared 84 neonates (51 males, 33 females, Table 2-1) from 23 May to 20 June 2014 and 73 neonates (44 males, 28 females, 1 unknown, Table 2-1) from 27 May to 23 June 2015 totaling 157 radio-collared neonates among study areas across years. We observed 2 capture-related fawn mortalities in Perkins County during 2015 and removed those individuals from survival analyses. Average age at capture was 7.1 ± 2.3 days (n = 157). Average mass at capture was 3.9 ± 0.9 kg (n = 157). There was no difference in mass at capture between study areas ($F_{2, 112}$ = 0.128, p = 0.88). Hoof growth varied ($F_{2, 112}$ = 4.225, p = 0.017) among study areas. Grant County had the highest mean hoof growth ($\bar{x}$ =3.29 mm SE = 0.15, n = 40) measure followed by Perkins ($\bar{x}$ = 2.94 mm SE = 0.12, n = 69) and Dunn ($\bar{x}$ = 2.59 mm SE = 0.17, n = 48) counties.

We radio-collared 58 and 99 fawns using VITs and opportunistic captures, respectively. There were 25% more searchers in South Dakota than North Dakota during fawn capture. We pooled fawn Julian birth and capture dates and masses from fawns in Dunn and Grant counties because search effort was similar. Fawns radio-collared using VITs in Dunn and Grant counties had a mean Julian birth date of 159 ± 1.0 (n = 44) and fawns captured opportunistically displayed a mean Julian capture date of 163±0.8 (n = 44, $F_{1, 86}$ = 6.579, p = 0.012). Mean Julian dates did not differ between VIT and opportunistically captured fawns ($F_{1, 67}$ = 1.41, p = 0.239) in Perkins County. North Dakota fawns captured using VITs averaged 3.5 ± 0.8 kg (n=39) at birth compared ($F_{1, 73}$ = 17.1, p <0.0001) to fawns captured opportunistically that averaged 4.2 ± 0.1 kg (n = 36) at capture. Mass of Perkins County fawns did not differ ($F_{1, 53} = 3.237$, $p = 0.077$) between fawns captured using VITs and those opportunistically captured.

We documented 44 (28%) fawn mortalities between capture and six-months of age with 30 and 14 mortalities recorded in 2014 and 2015, respectively (Table 2-2). We documented 28 (64%) male and 16 (36%) female mortalities across study areas and years. Predation was the primary source of natural mortality (61%), whereas hunter harvest (9%) was the only source of human-related mortality (Table 2-2). We observed 11 fawn mortalities (25% of total mortalities) across years in Dunn County, where natural causes accounted for 9 (82%) mortalities (Table 2-2). Fawns lost 7 and 2 collars in Dunn County during 2014 and 2015, respectively. We observed 18 fawn mortalities (41% of total mortalities) in Grant County across years, and natural causes accounted for 16 (89%) mortalities (Table 2-2). Fawns lost 1 and 3 collars in Grant County during 2014 and 2015, respectively. We censored 4 individuals in Grant County because we could not locate collar signals after capture. We observed one censored unknown mortality due to our inability to obtain landowner permission to investigate mortality signals, and no mortality was confirmed. We observed 15 fawn mortalities (34% of total mortalities) in Perkins County across years where 13 (87%) mortalities were from natural causes (Table 2-2). Fawns lost 5 and 7 collars in Perkins County during 2014 and 2015, respectively. Seven individuals were censored unknown mortalities due to our inability to obtain landowner permission to investigate mortality signals, and no mortalities were confirmed.

We observed several fawn mortalities due to birth defects during 2014. A male radio-collared fawn captured opportunistically on 15 June in Grant County was found dead near a farmstead on 21 June due to an incomplete urethra and was estimated to be 7 days old at capture. Another male fawn was found dead with deformed hooves in a birth site located using a VIT associated with Doe 250 in Dunn County on 7 June. We also radio-collared a fawn near the birth site associated with Doe 250 that survived past six-months of age. A male still born triplet was found in a birth site associated with Doe 270 in Dunn County on 19 June, but the other two fawns associated with Doe 270 were radio-collared and survived past six-months of age. A female fawn was found dead in a birth site located using a VIT associated with Doe 201 in Grant County on 11 June. The fawn had been killed by a large canid, most likely a domestic dog, and was left in the birth site fully intact. No other fawns associated with Doe 201 were found in the area. No birth defects, stillborn, or dead fawns were found during 2015.

We observed 11 and 0 fawn mortalities after six-months of age during 2014 and 2015, respectively. There were no fawn mortalities after six-months of age in Dunn County during 2014 or 2015. We censored 3 (27% of total mortalities) individuals after six-months of age in Grant County during 2014 because individuals could not be located via aerial or ground telemetry after six months and mortality was unknown. We suspect radio-collar batteries could have weakened over time preventing our ability to locate censored individuals. We observed 8 fawn mortalities (73% of total mortalities) after six months of age during 2014 in Perkins County. Mortality causes included: 1 censored unknown, 1 unknown, 1 suspected predation, 1 disease (lactic acidosis), and 1 illegal hunter harvest. The censored unknown mortality was transmitting a mortality signal from property we did not have permission to access, and mortality was not confirmed.

Model selection indicated that S(Capture) was our best approximating model describing variation in three- (w_i = 0.64, Table 2-3) and six-month (w_i = 0.46, Table 2-4) survival for our intrinsic model set. This model indicated that capture method influenced survival with opportunistically caught fawns displaying increased survival compared to fawns caught using the aid of VITs. Survival estimates for fawns captured using VITs during the three and six-month time periods were 0.62 (SE = 0.07) and 0.53 (SE = 0.07), respectively. Survival estimates for fawns caught opportunistically during the three- and six-month time periods were 0.84 (SE = 0.04) and 0.74 (SE = 0.05), respectively. Our results indicate that opportunistically captured fawns displayed 21% greater survival on average than fawns captured using VITs. Our second best model S(Age) was a competing model in the six-month model set but age was not a meaningful covariate (β = 0.08, 95% CI = -0.01 to 0.17).

Model selection indicated that S(Canopy+Precip2) was the best approximating model describing variation in three- (w_i = 0.40, Table 2-5) and six-month (w_i = 0.79, Table 2-6) fawn survival in our extrinsic candidate set. Canopy cover at capture sites (β = 0.02, 95% CI = 0.00 to 0.04) was meaningful during three-month survival models and positively influenced fawn survival. Precipitation during 3 to 8 weeks of age (β = -0.48, 95% CI = -0.83 to -0.13) was meaningful in six-month survival models and negatively influenced fawn survival. Survival estimates from our best model for the three and six-month periods were 0.80 (SE = 0.04) and 0.72 (SE = 0.04), respectively.

We also ran additional extrinsic models to assess the influence of energy development on six-month survival in Dunn County. Distance from fawn capture site to nearest oil well was included in the Dunn County model set. Model selection indicated that S(.) was our best approximating model (w_i = 0.32, Table 2-7) denoting that survival was constant over time. Our models that included distance to road (km), water body (km), oil well (km), and canopy cover (%) at capture site also were highly ranked (AIC_c w_i = 0.12, Table 2-7), but covariates were not meaningful (Table 2-8). Survival estimates from our best model for six-month periods in Dunn County was 0.74 (SE = 0.07).

Three and six-month survival estimates varied by year across study areas. The greatest estimated three-month survival was 0.93 (SE = 0.03, Table 2-9) in Dunn and Perkins counties in 2015. The greatest estimated six-month survival was 0.88 (SE = 0.04, Table 2-10) in Perkins County in 2015. The lowest estimated three- and six-month survival was 0.35 (SE = 0.10, Table 2-9) and 0.20 (SE = 0.08, Table 2-10), respectively, in Grant County during 2014.

Predator relative abundance varied among the 4 survey locations. We detected coyotes most frequently (64 detections at 30 stations), followed by badgers (*Taxidea taxus*; 7 detections at 6 stations) and red fox (*Vulpes vulpes*; 1 detection at 1 station). Calculated SSI was 65 for Dunn oil development, 69 for Dunn, 24 for Grant, and 43 for Perkins counties (Table 2-11).

The U. S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA APHIS) conducts annual coyote culling via aerial gunning in the three study areas. During 2014, APHIS removed 39, 173, and 263 coyotes in Dunn, Grant, and Perkins counties, respectively, and during 2015, removed 28, 162, and 292 coyotes in Dunn, Grant, and Perkins counties, respectively (P. Mastrangelo, USDA APHIS, personal communication). Before our camera scent-stations were deployed in 2015, APHIS removed 14, 108, and 55 coyotes from Dunn, Grant and Perkins counties, respectively (P. Mastrangelo, USDA APHIS, personal communication).

Calculated DWSI was similar across study areas. In Dunn County, the average DWSI for the winters of 2013-2014 and 2014-2015 was 117 and 96, respectively (Figure 2-3). In Grant County, the average DWSI for the winters of 2013-2014 and 2014-2015 was 107 and 93, respectively (Figure 2-3). In Perkins County, the average DWSI for 2013-2014 and 2014-2015 winters was 132 and 97, respectively (Figure 2-3).

DISCUSSION

Our results do not support our prediction that oil and natural gas development would negatively impact white-tailed deer fawn survival or cause-specific mortality in the western Dakotas. Fawn survival in Dunn County was similar to that in Perkins County despite the presence of oil and natural gas development; however Grant County displayed the lowest survival. High survival rates in Dunn County could indicate that effects of oil and natural gas development were experienced before our study occurred, or that a lag in response to development is occurring (Beckmann et al. 2008). Literature reports inconsistent results from the impacts of development on wildlife species. Ciuti et al. (2014) reported the potential interaction of habitat fragmentation from roads created by energy development and increased coyote predation on mule deer fawns. However, Beckmann et al. (2008) reported no difference in pronghorn fawn recruitment between energy development and undeveloped areas, because habitat loss due to energy development did not decrease carrying capacity of pronghorn in Wyoming. Low deer density in Dunn County compared to the other study areas could have provided abundant cover and resources away from energy development areas, thereby allowing neonates to avoid mortality associated with oil and natural gas development.

Our intrinsic model set provided support for previous research findings that suggest using VITs to locate and radio-collar fawns shortly after birth allows researchers to monitor fawns when they are most susceptible to mortality (Rohm et al. 2007, Grovenburg et al. 2011). Fawns captured using the aid of VITs during this study displayed 21 and 22% lower survival rates than fawns caught opportunistically at three- and six-months of age, respectively, and supported the findings of Gilbert et al. (2014; 23% survival difference). Gilbert et al. (2014) modeled fawn survival using left truncated (opportunistically captured fawns) and non-truncated (fawns captured using VITs) data and found that survival estimates were significantly higher when using left truncated data. Left truncated data also biased environmental variables by changing the magnitude and sign of coefficients in survival models altering the relationships seen in non-truncated survival models (Gilbert et al. 2014). Gilbert et al. (2014) suggests using a subset of neonatal captures when estimating survival to correct survival estimates calculated from left truncated data alone.

Using VITs to aid in radio-collaring of neonates helps identify mortalities early in fawn life, but we were unable to radio-collar and document mortality of neonates that died quickly due to disease and birth defects. It is unknown how many neonates died at birth but were scavenged by predators before we discovered the carcasses. Many radio-collared fawn carcasses were partially or completely scavenged during this study, which inhibited our ability to determine a proximate cause of death during necropsy. Collecting intact carcasses could have provided clearer answers on how disease and birth defects impacted fawn survival. Perhaps the difference in survival estimated by Gilbert et al.

(2014) is larger than 23% because fawns die quickly from disease and birth defects, and may be missed even when using VITs to locate birth sites.

We used measured hoof growth at capture to estimate fawn age in our S(Age) model, but potential inaccuracies can occur when multiple observers measure fawn hoof growth in the first days of life (Sams et al. 1996, Carstensen et al. 2009, Gilbert et al. 2014). Inaccuracies in hoof growth measures could have caused S(Mass) to be a low approximating model because inaccurate hoof growth measures could have caused inconsistencies when calculating birth mass. Opportunistically caught fawns were older than their counterparts captured using VITs, because opportunistically caught fawns were heavier and found at later Julian dates. Thus, we hypothesize that our second best model, S(Age), was influenced by our capture method. Fawns captured using VITs had lower survival rates than opportunistically caught fawns because we were able to document mortality when fawns were most vulnerable in the first days of life. Younger fawns from females with VITs were susceptible to predation, disease, and birth defects, whereas older, opportunistically captured fawns avoided those mortality causes and biased our survival estimates when capture type was not included in the model. Our results did not fully support this conclusion as we observed most of our mortalities for both capture types during 3 to 8 weeks of life. Disproportionate numbers of fawns captured using VITs compared to opportunistically captured fawns may have contributed to this result. A larger sample size of fawns captured using VITs could have clarified why survival differed, but more research is needed to determine why differences in survival occur between fawns captured from VITs and opportunistically captured fawns.

Our results showed that canopy cover (%) at birth sites positively influenced three-month survival, and precipitation during 3 to 8 weeks of life negatively influenced six-month survival. Canopy cover is important for fawn survival because it protects fawns from rainfall, helps regulate internal temperature, and provides cover and concealment while fawns display a hider strategy during the first weeks of life (Nelson and Woolf 1987, Rohm et al. 2007). Fawns transition from using a hider strategy to outrunning predators between 3 and 8 weeks of age (Nelson and Woolf 1987), and during that transition, exposure to adverse weather conditions may cause mortality or increase mortality risk associated with other factors such as predation. We observed the majority of our fawn mortality during 3 to 8 weeks of age similar to Nelson and Woolf (1987). We hypothesize that fawns were more exposed to adverse weather conditions and predators during the transition from a hider strategy to following mothers at heel, which increased their mortality risk.

Our extrinsic model set investigating how energy development affected fawn six-month survival in Dunn County suggested that fawn survival did not vary across time. There also were several competing models, but the covariates distance to road, oil well, and water body were not meaningful. We expected fawns to be near water sources because females need access to water while lactating (Adams and Hayes 2008, Long et al. 2009, Ditchkoff 2011). We also expected fawns to be away from roads and oil well sites, because females would be disturbed by traffic and human activity (Rost and Bailey 1979, Stankowich 2008). Covariates distance to road, oil well, and water body may not have been effective predictors because Dunn County had a low mortality rate (23%) compared to Grant and Perkins counties (45 and 22%, respectively). Distance to water body was not a meaningful covariate for six-month survival, but may be more important for fawn survival under three months of age when fawns rely on milk production. Females in Dunn County also may have avoided areas of development, disturbance, and traffic when raising fawns, or in some cases, have acclimated to those disturbances resulting in similar distance covariates.

Three-month survival (0.84) in Dunn and Perkins counties was similar to survival observed during other three-month survival studies in southwestern Minnesota (0.79, Brinkman et al. 2005) and in southeastern Lower Michigan (0.91, Pusateri Burroughs et al. 2006). Fawn six-month survival in Dunn and Perkins counties (0.75 and 0.78, respectively) was similar to other survival studies in the southern Black Hills (0.60, Schmitz 2006) and southeastern Lower Michigan (0.81, Pusateri Burroughs et al. 2006). Fawns in Dunn and Perkins counties may benefit from ample summer cover provided by quality habitat due to lower deer density compared to potentially less quality habitat available due to higher deer density in Grant County (Nixon et al. 1991, Brinkman et al. 2004, Heffelfinger 2011).

Grant County three-month survival (0.55) was lower than survival in Dunn and Perkins counties, but similar to survival observed during other three-month survival studies in eastern (0.57, Sternhagen 2015) and central (0.61, Schaffer 2013) North Dakota, north central Minnesota (0.53, Carstensen et al. 2009), and southern Illinois (0.30, Nelson and Woolf 1987). Grant County six-month survival (0.40) was similar to survival observed in six-month survival studies in Alabama (0.26, Jackson and Ditchkoff 2013), south-central Iowa (0.27, Huegel et al. 1985), coastal South Carolina (0.48, McCoy et al. 2013), southern Illinois (0.59, Rohm et al. 2007), and Pennsylvania (0.53, Vreeland et al. 2004). Low fawn survival in Grant County compared to Dunn and Perkins counties may be explained by the confounding effects of weather, habitat conditions, and density dependence (Bergman et al. 2015).

Low three- and six-month survival in Grant County may indicate that density dependent factors were impacting the deer population. A deer population at or near carrying capacity is likely to have higher fawn mortality and low recruitment (McCullough 1979, Sams et al. 1996, Ricca et al. 2002), but carrying capacity can be difficult to quantify during short-term studies (White and Bartmann 1998). Density dependence may not be driving population dynamics in the western Dakotas, but a long-term study in the region would clarify density dependent and independent factors impacting the population. Higher deer density in Grant County compared to Dunn and Perkins counties could be decreasing the amount of quality forage available to females leaving poorer quality forage and/or bedding sites on the landscape, which could limit reproduction and survival, and prevent population increase (DeYoung 2011).

Maternal body condition influences ungulate neonatal survival (Mech et al. 1987, Ditchkoff 2011, Monteith et al. 2014, Duquette et al. 2015). Decker et al. (1992) suggested that high fawn mortality is related to poor herd health and habitat conditions. Shallow et al. (2015) stated that habitat characteristics impact physical condition, reproduction, and survival. Milk production can be negatively affected by low nutrient availability and female body condition (Ditchkoff 2011). Verme (1969) found that yearlings fed high-quality forage were 2.5 times more productive than yearlings on poor quality forage. Duquette et al. (2015) reported that fawn survival was most influenced by female nutrition and winter severity and female nutrition explained over 60% of the variation in fawn survival. Multiple severe winters also negatively influences maternal condition (Mech et al. 1987). Maternal body condition in the western Dakotas has likely been negatively impacted by high winter severity for a number of years, which may have caused lower maternal nutrition, smaller fawns, and low fawn survival during 2014 compared to 2015 (Ditchkoff 2011, Monteith et al. 2014, Duquette et al. 2015). Maternal body condition also may be related to low observed fawn survival in Grant County.

We surveyed relative predator abundance in 2015 after observing high fawn mortality during 2014. Our predator surveys indicated that predator abundance varied among study areas but was similar between development and non-developed areas in Dunn County. Coyotes have exhibited tolerance to human activities and fragmented landscapes and may benefit from anthropogenic landscape changes (Tigas et al. 2002, Atwood et al. 2004, George and Crooks 2006, Ordeñana et al. 2010), which may explain why Dunn County predator abundance was high even in an area of oil and natural gas development. High predator abundance in oil and natural gas development in Dunn County contradicts Burr (2014) who reported a negative relationship between predator occurrence and energy development. Grant County displayed the lowest relative predator abundance and the highest number of predation mortalities suggesting that a disproportionate amount of predation occurred in Grant County. However, USDA APHIS removes coyotes from the landscape via aerial gunning annually, and each study area had similar numbers of coyotes removed during 2014 and 2015. By 1 April 2015 (the start date for our predator index), USDA APHIS removed 67% of its total 2015 coyote take in Grant County compared to 50 and 19% in Dunn and Perkins counties; respectively. Increased coyote removal prior to our predator survey during 2015 may explain the low predator abundance in Grant County. Coyote abundance may be better assessed in all study areas after or before annual gunning.

The extent of predation of fawns up to six-months of age varies among regions in the United States. For example, in the Northern Great Plains, fawn predation in southwestern Minnesota (67%, Brinkman et al. 2004) and eastern South Dakota (80%, Grovenburg et al. 2011) was equal to or higher than in Dunn (64%), Grant (67%), and Perkins (53%) counties. Fawn predation also varies greatly across the Midwest and eastern regions of the U. S. Reported fawn predation rates were as follows: Iowa (21%, Huegel et al. 1985), Lower Michigan (14%, Pusateri Burroughs et al. 2006), southern Illinois (69%, Nelson and Woolf 1987; 64%, Rohm et al. 2007), and Pennsylvania (46%, Vreeland et al. 2004). High coyote predation in the southeast has been observed in Alabama (67%, Saalfeld and Ditchkoff 2007; 86% Jackson and Ditchkoff 2013) and South Carolina (78% Kilgo et al. 2012; 43% McCoy et al. 2013), and substantially lowered fawn recruitment. Our predation rates and primary cause of mortality (predation) was similar to those displayed by other studies across North America.

Our results indicated that energy development has not resulted in a detectable negative impact on white-tailed deer fawn survival in the western Dakotas. White-tailed deer are an adaptive and opportunistic species that have benefited from anthropomorphic landscape changes (Nixon et al. 1991, Brinkman et al. 2004, Ballard 2011). However, other species of ungulates and nongame species may respond differently to energy development in the region. For example, sage grouse (*Centrocercus urophasianus*; Riley et al. 2012) populations and pronghorn movements (Christie et al. 2015) are negatively affected by fencing, vehicle collisions, and well density in energy development areas.

The interaction of energy development and coyote predation also could impact neonatal recruitment and increase the complexity of assessing these relationships (Ciuti et al. 2014). Additional research on fawn survival in areas of low and high energy development with similar deer density may clarify impacts of oil and natural gas development on fawn survival and cause-specific mortality. Long-term studies are needed to further assess the influence of energy development on neonatal survival and to identify potential lags in response to development (Beckmann et al. 2008).

MANAGEMENT IMPLICATIONS

Wildlife managers should continue to provide cover and resources away from oil and natural gas development areas to prevent fawn mortalities related to energy development. Researchers should use consistent methodology and adequate numbers of searchers (>10 personnel) while capturing fawns to decrease survival estimate bias when VITs are not used to capture neonates. If the population is limited by density dependent factors, increased deer harvest in Grant County also could decrease competition for resources and allow recruitment rates to recover. Increasing quality winter deer range will help to decrease intraspecific competition during severe weather, and thereby increase maternal condition.

LITERATURE CITED

Adams, R. A., and M. A. Hayes. 2008. Water availability and successful lactation by bats as related to climate change in arid regions of western North America. Journal of Animal Ecology 77:1115-1121.

Atwood, T. C., H. P. Weeks, T. M. Gehring, and J. White. 2004. Spatial ecology of coyotes along a suburban-to-rural gradient. Journal of Wildlife Management 68:1000-1009.

Ballard, W. 2011. Predator-prey relationships. Pages 251-286 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Barbknecht, A. E., W. S. Fairbanks, J. D. Rogerson, E. J. Maichak, and L. L. Meadows. 2008. Effectiveness of vaginal-implant transmitters for locating elk parturition sites. Journal of Wildlife Management 73:144-148.

Beckmann, J. P., K. M. Berger, J. K. Young, and J. Berger. 2008. Wildlife and energy development: pronghorn of the Upper Green River Basin – year 3 summary. Wildlife Conservation Society, Bronx, NY. <http://www.wcs.org/yellowstone> Accessed 14 June 2016.

Berger, J., J. E. Swenson, and I. Persson. 2001. Recolonizing carnivores and naïve prey: conservation lessons from Pleistocene extinctions. Science 291:1036-1039.

Bergman, E. J., P. F. Doherty, Jr., G. C. White, and A. A. Holland. 2015. Density dependence in mule deer: a review of evidence. Wildlife Biology 21:18-29.

Bishop, C. J., D. J. Freddy, G. C. White, B. E. Watkins, T. R. Stephenson, and L. L. Wolfe. 2006. Using vaginal implant transmitters to aid in capture of mule deer neonates. Journal of Wildlife Management 71:945-954.

Bowman, J. L. and H. A. Jacobson. 1998. An improved vaginal-implant transmitter for locating white-tailed deer birth sites and fawns. Wildlife Society Bulletin 26:295-298.

Brinkman, T. J., K. L. Monteith, J. A. Jenks, and C. S. Deperno. 2004. Predicting neonatal age of white-tailed deer in the Northern Great Plains. The Prairie Naturalist 36:75-81.

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

Burnham, K. P.; Anderson, D. R. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach (2nd ed.), Springer-Verlag, ISBN 0-387-95364-7.

Burr, P. C. 2014. Impacts of gas and oil development on sharp-tailed grouse (*Tympanuchus phasianellus*) nest success and predator dynamics in western North Dakota. Thesis, University of North Dakota, Grand Forks, USA.

Bryce, S. J., M. Omernik, D. E. Pater, M. Ulmer, J. Schaar, J. Freeouf, R. Johnson, P. Kuck, and S. H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. (Map poster). U.S. Geological Survey, Jamestown, ND.

Carstensen, M., G. D. DelGiudice, B. A. Sampson, and D. W. Kuehn. 2009. Survival, birth characteristics, and cause-specific mortality of white-tailed deer neonates. Journal of Wildlife Management 73:175–183.

Christie, K. S., W. F. Jensen, J H. Schmidt, M.S. Boyce. 2015. Long-term changes in pronghorn abundance index linked to climate and oil development in North Dakota. Biological Conservation 192:445-453.

Ciuti, S., W. F. Jensen, S. E. Nielsen, and M. S. Boyce. 2014. An evaluation of historical mule deer fawn recruitment in North Dakota. Report prepared for North Dakota Game and Fish Department.

Conner, L. M., M. J. Cherry, B. T. Rutledge, C. H. Killmaster, G. Morris, and L. L. Smith. 2016. Predator exclusion as a management option for increasing white-tailed deer recruitment. The Journal of Wildlife Management 80:162-170.

Cooch, E., and G. C. White. 2016. Program Mark: a gentle introduction. Sixteenth edition. Department of Natural Resources, Cornell University, Ithaca, NY, USA.

Decker, T. A., W. H. Healy, and S. A. Williams. 1992. Survival of white-tailed deer fawns in western Massachusetts. Northeast Wildlife 49:28–35.

Department of Mineral Resources [DMR] Oil and Gas Division. 2016. DMR Homepage. <https://www.dmr.nd.gov/> Accessed 14 June 2016.

DeYoung, C. A. 2011. Population dynamics. Pages 147-180 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Diefenbach, D. R., M. J. Conroy, R. J. Warren, W. E. James, L. A. Baker, and T. Hon. 1994. A test of scent-station survey technique for bobcats. Journal of Wildlife Management 58:10-17.

Ditchkoff, S. S. 2011. Anatomy and physiology. Pages 43-73 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Duquette, J. F., J. L. Belant, N. J. Svoboda, D. E. Beyer, and P. E. Lederle. 2015. Scale dependence of female ungulate reproductive success in relation to nutritional condition, resource selection and multi-predator avoidance. PLoS ONE 10(10):e0140433. doi:10.1371/ journal.pone.0140433

Dyer, S., J. O'Neill, S. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. Journal of Wildlife Management 65: 531-542.

Dyke, S., D. Fryda, D. Kleyer, J. Williams, B. Hosek, W. Jensen, S. Johnson, A. Robinson, F. Ryckman, B. Stillings, M. Szymanski, S. Tucker, and B. Wiedmann. 2011. Potential impacts of oil and gas development on select North Dakota natural resources; a report to the director. North Dakota Game and Fish Department.

Frair, J. L. 2005. Survival and movement behaviour of resident and translocated wapiti (*Cervus elaphus*): implications for their management in west-central Alberta, Canada. University of Alberta. Edmonton, Alberta, Canada.

Gilbert S. L., M. S. Lindeberg, K. J. Hundertmark, and D. K. Person. 2014. Dead before detection: addressing the effects of left truncation on survival estimation and ecological inference for neonates. Methods in Ecology and Evolution 5:992-1001.

George, S. L., and K. R. Crooks. 2006. Recreation and large mammal activity in an urban nature reserve. Biological Conservation 133:107-117.

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

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

Grovenburg, T. W., K. L. Monteith, C. N. Jacques, R. W. Klaver, C. S. DePerno, T. J. Brinkman, K. B. Monteith, S. L. Gilbert, J. B. Smith, V. C. Bleich, C. C. Swanson, and J. A. Jenks. 2014. Re-evaluating neonatal-age models for ungulates: does model choice affect survival estimates? PLoS ONE 9:e108797. doi:10.1371/journal.pone.0108797

Haugen, A. O., and D. W. Speake. 1958. Determining age of young fawn white-tailed deer. Journal of Wildlife Management 22:319-321.

Heffelfinger, J. R. 2011. Taxonomy, evolutionary history, and distribution. Pages 3-39 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Huegel, C. N., R. B. Dahlgren, and H. L. Gladfelter. 1985. Mortality of white-tailed deer fawns in south-central Iowa. Journal of Wildlife Management 22:319-321.

Jackson, A. M., and S. S. Ditchkoff. 2013. Survival estimates of white-tailed deer fawns at Fort Rucker, Alabama. American Midland Naturalist 170:184-190.

Johnson, B. 1980. Response of elk during calving to oil gas drilling activity in Snider Basin, Wyoming, Wyoming Game and Fish Department.

Johnstone-Yellin, T. L., L. A. Shipley, and W. L. Myers. 2006. Effectiveness of vaginal implant transmitters for locating neonatal mule deer. Wildlife Society Bulletin 34:338-344.

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

Kilgo, J. C., H.S. Ray, M. Vukovich, M. J. Goode, and C. Ruth. 2012. Predation by coyotes on white-tailed deer neonates in South Carolina. Journal of Wildlife Management 76:1420-1430.

Linhart, S. B., and F. F. Knowlton. 1975. Determining the relative abundance of coyotes by scent station lines. Wildlife Society Bulletin 3:119-124.

Long, R. A., J. G. Kie, R. T. Bowyer, and M. A. Hurley. 2009. Resource selection and movements by female mule deer *Odocoileus hemionus*: Effects of reproductive stage. Wildlife Biology 15:288-298.

McCormick, M. I. and T. H. Holmes. 2005. Prey experience of predation influences mortality rates at settlement in a coral reef fish *Pomacentrus amboinensis*. Journal of Fish Biology 68:969-974.

McCoy, J. C., S. S. Ditchkoff, J. B. Raglin, B. A. Collier, and C. Ruth. 2013. Factors influencing survival of white-tailed deer fawns in coastal South Carolina. Journal of Fish and Wildlife Management 4:280-289.

McCullough, D. R. 1979. The George Reserve deer herd: population ecology of a K-selected species. University of Michigan Press, Ann Arbor, USA

Mech, L. D., R. E. McRoberts, R. O. Peterson, and R. E. Page. 1987. Relationship of deer and moose populations to previous winters' snow. Journal of Animal Ecology 56:615-627.

Michel, E. S., S. Demarais, B. K. Strickland, and J. L. Belant. 2015. Contrasting the effects of maternal and behavioral characteristics of fawn birth mass in white-tailed deer. PLoS ONE 10(8): e0136034. Doi:10.1371/journal.pone.0136034.

Monteith, K. L., V. C. Bleich, T. R. Stephenson, B. M. Pierce, M. M. Conner, J. G. Kie, and R. T. Bowyer. 2014. Life-history characteristics of mule deer: effects of nutrition in a variable environment. Wildlife Monographs 186:1-56.

Nelson, T. A., and A. Woolf. 1987. Mortality of white-tailed deer fawns in southern Illinois. Journal of Wildlife Management 51:326–329.

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

North Dakota State Climate Office. 2016. Monthly station normal of temperature, precipitation, and heating and cooling degree days 1981-2010. <https://www.ndsu.edu/ndsco/data/30yearaverage/#c343059>.

Accessed 12 July 2016

Ordeñana, M. A., K. R. Crooks, E. E. Boydston, R. N. Fisher, L. M. Lyren, S. Siudyla, C. D. Haas, S. Harris, S. A. Hathaway, and G. M. Turschak. 2010. Effects of urbanization on carnivore species distribution and richness. Journal of Mammalogy 91:1322-1331.

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

Pusateri Burroughs, J., III, H. Campa, S. R. Winterstein, B. A. Rudolph, and W. E. Moritz. 2006. Cause-specific mortality and survival of whitetailed deer fawns in southwestern Lower Michigan. Journal of Wildlife Management 70:743–751.

Ricca, M. A., R. G. Anthony, D. H. Jackson and S. A. Wolfe. 2002. Survival of Columbian white-tailed deer in western Oregon. The Journal of Wildlife Management 66:1255-1266.

Riley, T. R., E. M. Bayne, B. C. Dale, D. E. Naugle, J. A. Rodgers, and S. C. Torbit. 2012. Impacts of crude oil and natural gas developments on wildlife and wildlife habitat in the Rocky Mountain region. Technical Review prepared for The Wildlife Society, Bethesda, MD.

Rohm, J. H., C. K. Nielsen, and A. Woolf. 2007. Survival of white-tailed deer fawns in southern Illinois. Journal of Wildlife Management 71:851–860.

Rost, G. and J. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43:634-641.

Saalfeld, S. T., and S. S. Ditchkoff. 2007. Survival of neonatal white-tailed deer in an exurban population. Journal of Wildlife Management 71:940-944.

Sams, M.G., R. L. Lochmiller, E. C. Hellgren, W. D. Warde, L. W. Varner, and D. Warde. 1996. Morphometric predictors of neonatal age for white-tailed deer. Wildlife Society Bulletin, 24:53–57.

Sawyer, H., R. Nielson, D. Stickland, and L. McDonald. 2005. Mule Deer Study (Phase II): Long-term Monitoring Plan to Assess Potential Impacts of Energy Development on Mule Deer in the Pinedale Anticline Project Area. Western Ecosystems Technology, Inc., Cheyenne, WY.

Sawyer, H., R. Nielson, F. Lindzey, and L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. Journal of Wildlife Management 70:396-403.

Schaffer, B. A. 2013. An evaluation of life history parameters of white-tailed deer (*Odocoileus virginianus*) in North Dakota. Thesis, South Dakota State University, Brookings, USA.

Schmitz, L. E. 2006. Ecology of white-tailed deer in South Dakota: growth, survival, and winter nutrition. Thesis, South Dakota State University, Brookings, USA.

Sedivec, K. K., T. D. A. Tober, W. L. Duckwitz, and J. R. Hendrickson. 2011. North Dakota State University Extension Service. Grass varieties for North Dakota. <https://www.ag.ndsu.edu/pubs/plantsci/hay/r794.pdf> Accessed 17 June 2016.

Shallow, J. R. T., M. A. Hurley, K. L. Monteith, and R. T. Bowyer. 2015. Cascading effects of habitat on maternal condition and life-history characteristics of neonatal mule deer. Journal of Mammalogy 96:194-205.

Sih, A., D. I. bolnick, B. Luttbeg, J. L. Orrock, S. D. Peacor, L. M. Pintor, E. Preisser, J. S. Rehage, and J. R. Vonesh. 2010. Predator-prey naiveté, antipredator behavior, and the ecology of predator invasions. Oikos 119:510-621.

Sikes, R. S., and the Animal Care and Use Committee of the American Society of Mammalogists. 2016. 2016 Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy Volume 97, Issue 3, pages 663—688.

Smith, G. R., A. Boyd, C. B. Dayer, and K. E. Winter. 2008. Behavioral Responses of American toad and bullfrog tadpoles to the presence of cues from the invasive fish, *Gambusia affinis*. Biological Invasions 10:743-748.

South Dakota Department of Environment and Natural Resources [DENR]. 2016. DENR homepage. http://denr.sd.gov>Accessed 14 June 2016.

Stankowich, T. 2008. Ungulate flight responses to human disturbance: a review and meta-analysis. Biological Conservation 141:2159-2173.

Stillings, B., B. Jensen, and J. Smith. 2012. Study No. C-I: Deer population studies. North Dakota Game and Fish Department. Bismarck, ND, USA.

Sternhagen, K. M. 2015. An evaluation of life history parameters and management of white-tailed deer (*Odocoileus virginianus*) in the Red River valley of northeastern North Dakota. Thesis, South Dakota State University, Brookings, USA.

Swanson, C. C., J. A. Jenks, C. S. DePerno, R. W. Klaver, R. G. Osborn, and J. A. Tardiff. 2008. Does the use of vaginal implant transmitters impact neonate survival of white-tailed deer? Wildlife Biology 14:272-279.

Tigas, L. A., D. H. Van Vuren, and R. M. Sauvajot. 1999. Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. Biological Conservation 108:299-306.

U. S. Department of Agriculture (USDA). 2015. USDA, National Agricultural Statistics Service (NASS), Cropland Data Layer. USDA, NASS Marketing and Information Services Office, Washington, D.C., USA.

U. S. Department of Energy. 2014. U. S. Energy Information Administration, Rankings: Total Energy Consumed per Capita, 2014. Energy Information Administration Office, Washington, D. C., USA.

U. S. Geological Survey (USGS). 2 May 2013. USGS releases new oil and gas assessment for Bakken and Three Forks Formations. <https://www2.usgs.gov/blogs/features/ usgs_top_story/usgs-releases-new-oil-and-gas-assessment-for-bakken-and-three-forks-formations/> Accessed 6 April 2016.

Verme, L. J. 1963. Effect of nutrition on growth of white-tailed deer fawns. Michigan Department of Natural Resources, Cusino Wildlife Experiment Station, Shingleton, Michigan, USA.

Verme, L. J. 1969. Reproductive patterns of white-tailed deer related to nutritional plane. 1969. Journal of Wildlife Management 33:881-887.

Vreeland, J. K., D. R. Diefenbach, and B. D. Wallingford. 2004. Survival rates, mortality causes, and habitats of Pennsylvania white-tailed deer fawns. Wildlife Society Bulletin 32:542–553.

White, G. C. and R. M. Bartmann. 1998. Effect of density reduction on overwinter survival of free ranging mule deer. Journal of Wildlife Management 62:214-225.

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

Table 2-1. Radio-collared neonate white-tailed deer captured in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

		Counties			
Year	**Sex**	**Dunn**	**Grant**	**Perkins**	**Total**
2014	Males	16	13	22	51
	Females	13	7	13	33
	Year Total	29	20	35	84
2015	Males	9	14	21	44
	Females	10	6	12	28
	Unknown	0	0	1	1
	Year Total	19	20	34	73

Table 2-2. Cause-specific mortality for six-month-old radio-collared white-tailed deer fawns in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

	Counties						
	Dunn		Grant		Perkins		
Cause of Mortality	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**Total**
Predation	4	3	3	3	3	0	16
Suspected Predation	0	0	5	1	4	1	11
Unknown	1	0	2	1	1	2	7
Disease	1	0	1	0	2	0	4
Abandoned	1	0	0	0	0	1	2
Harvest	0	1	1	1	1	0	4
Total	7	4	12	6	11	4	44

Table 2-3. A *priori* intrinsic models used to estimate three-month survival of radio-collared white-tailed deer fawns in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

Model	AIC_c[a]	ΔAIC_c[b]	w_i[c]	K[d]	Deviance
S(Capture)	320.32	0.00	0.64	2.00	316.31
S(Age)	323.61	3.30	0.12	2.00	319.61
S(Int2)	324.91	4.59	0.06	3.00	318.89
(Ag+Sex)	325.52	5.20	0.05	3.00	319.50
S(Age+Mass)	325.62	5.30	0.05	3.00	319.60
S(.)	327.14	6.83	0.02	1.00	325.14
S(Age+Mass+Sex)	327.53	7.21	0.02	4.00	319.50
S(Mass)	327.72	7.40	0.02	2.00	323.71
S(Int1)	328.34	8.03	0.01	2.00	324.33
S(Sex)	329.13	8.81	0.01	2.00	325.12
S(Mass+Sex)	329.70	9.38	0.01	3.00	323.68
S(t)	336.17	15.86	0.00	36.00	262.36

[a] Akaike's Information Criterion (Burnham and Anderson 2002).
[b] Difference in AIC_c relative to minimum AIC.
[c] Akaike weight (Burnham and Anderson 2002).
[d] Number of parameters.

Table 2-4. A *priori* intrinsic models used to estimate six-month survival of radio-collared white-tailed deer fawns in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

Model	AIC_c[a]	ΔAIC_c[b]	w_i[c]	K[d]	Deviance
S(Capture)	426.02	0.00	0.46	2.00	422.02
S(Age)	428.01	1.99	0.17	2.00	424.01
S(.)	429.31	3.29	0.09	1.00	427.30
S(Mass)	429.94	3.91	0.07	2.00	425.93
S(Age+Mass)	429.99	3.97	0.06	3.00	423.98
S(Age+Sex)	430.00	3.97	0.06	3.00	423.99
S(Sex)	431.31	5.29	0.03	2.00	427.30
S(Mass+Sex)	431.94	5.92	0.02	3.00	425.93
S(Age+Mass+Sex)	431.97	5.95	0.02	4.00	423.96
S(t)	471.96	45.94	0.00	80.00	307.17

[a] Akaike's Information Criterion (Burnham and Anderson 2002).
[b] Difference in AIC_c relative to minimum AIC.
[c] Akaike weight (Burnham and Anderson 2002).
[d] Number of parameters.

Table 2-5. A *priori* extrinsic models used to estimate three-month survival of radio-collared white-tailed deer fawns in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

Model	AIC_c[a]	ΔAIC_c[b]	w_i[c]	K[d]	Deviance
S(Canopy+Precip2)[e]	314.32	0.00	0.40	4	306.29
S(Canopy)	314.78	0.46	0.32	3	308.76
S(Canopy+Precip3)[e]	316.38	2.06	0.14	4	308.36
S(Canopy+Precip1)[e]	316.63	2.31	0.13	4	308.60
S(Road)	321.68	7.36	0.01	3	315.66
S(Water)	322.21	7.89	0.01	3	316.19
S(.)	327.14	12.82	0.00	1	325.14
S(t)	336.17	21.86	0.00	36	262.37

[a] Akaike's Information Criterion (Burnham and Anderson 2002).

[b] Difference in AIC_c relative to minimum AIC.

[c] Akaike weight (Burnham and Anderson 2002).

[d] Number of parameters.

[e] Precipitation Intervals (1: 0-2 weeks; 2: 3-8 weeks; 3: 9-12 weeks)

Table 2-6. A *priori* extrinsic models used to estimate six-month survival of radio-collared white-tailed deer fawns in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

Model	AIC_c[a]	ΔAIC_c[b]	w_i[c]	K[d]	Deviance
S(Canopy+Precip2)[e]	378.70	0.00	0.79	4	370.68
S(Canopy)	383.54	4.84	0.07	3	377.53
S(Canopy+Precip1)[e]	383.97	5.27	0.06	4	375.96
S(Canopy+Precip3)[e]	384.88	6.18	0.04	4	376.87
S(Canopy+Precip4)[e]	385.49	6.79	0.03	4	377.47
S(Road)	387.65	8.95	0.01	3	381.64
S(Water)	387.93	9.24	0.01	3	381.93
S(.)	390.46	11.76	0.00	1	388.46
S(t)	426.77	48.08	0.00	74	274.40

[a] Akaike's Information Criterion (Burnham and Anderson 2002).
[b] Difference in AIC_c relative to minimum AIC.
[c] Akaike weight (Burnham and Anderson 2002).
[d] Number of parameters.
[e] Precipitation Intervals (1: 0-2 weeks; 2: 3-8 weeks; 3: 9-12 weeks; 4: 12-24 weeks)

Table 2-7. A *priori* extrinsic models used to estimate six-month survival of radio-collared white-tailed deer fawns in Dunn County, North Dakota, USA during 2014 and 2015.

Model	AIC_c[a]	ΔAIC_c[b]	w_i[c]	K[d]	Deviance
S(.)	113.24	0.00	0.32	2	109.23
S(Road)	115.24	2.00	0.12	3	109.21
S(Canopy)	115.24	2.00	0.12	3	109.21
S(Oil)	115.25	2.00	0.12	3	109.22
S(Water)	115.25	2.01	0.12	3	109.23
S(Canopy+Precip1)[e]	115.94	2.70	0.08	4	107.89
S(Canopy+Precip2)[e]	117.11	3.87	0.05	4	109.06
S(Canopy+Precip3)[e]	117.18	3.94	0.04	4	109.13
S(Canopy+Precip4)[e]	117.22	3.98	0.04	4	109.17
S(t)	121.27	8.03	0.01	24	71.85

[a] Akaike's Information Criterion (Burnham and Anderson 2002).

[b] Difference in AIC_c relative to minimum AIC.

[c] Akaike weight (Burnham and Anderson 2002).

[d] Number of parameters.

[e] Precipitation Intervals (1: 0-2 weeks; 2: 3-8 weeks; 3: 9-12 weeks; 4: 12-24 weeks)

Table 2-8. Covariate beta estimates, standard error, and 95% confidence intervals for six-month survival of radio-collared white-tailed deer fawns in Dunn County, North Dakota, USA during 2014 and 2015.

Covariate	Estimate	SE	95% CI Lower	95% CI Upper
Water Source	0.00	0.01	-0.02	0.03
Oil Pad	-0.21	0.56	-1.30	0.88
Canopy Cover	-0.19	0.63	-1.42	1.05
Road	0.19	0.63	-1.05	1.42

Table 2-9. Three-month survival rates for radio-collared white-tailed deer fawns in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

County	Year	Estimate	SE	95% CI Lower	95% CI Upper
Dunn	2014	0.75	0.08	0.56	0.87
	2015	0.93	0.03	0.83	0.97
Grant	2014	0.35	0.10	0.18	0.56
	2015	0.75	0.08	0.56	0.88
Perkins	2014	0.75	0.07	0.59	0.86
	2015	0.93	0.03	0.84	0.97

Table 2-10. Six-month survival rates for radio-collared white-tailed deer fawns in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

County	Year	Estimate	SE	95% CI Lower	95% CI Upper
Dunn	2014	0.63	0.09	0.45	0.78
	2015	0.86	0.05	0.72	0.94
Grant	2014	0.20	0.08	0.08	0.42
	2015	0.60	0.10	0.39	0.78
Perkins	2014	0.67	0.08	0.50	0.81
	2015	0.88	0.04	0.76	0.94

Table 2-11. Relative abundance of select predator species using camera scent-station surveys in April and May 2015 in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA.

Location	Species Recorded			Total # Predators	SSI[a]
	Coyote	Red Fox	Badger		
Dunn (Oil Development[b])	20	0	1	21	65
Dunn	21	0	0	21	69
Grant	5	0	3	8	24
Perkins	18	1	3	22	43

[a] Scent Survey Index = total # predator visits/total # operative station nights x 1,000
[b] 0.318 active oil wells/km^2

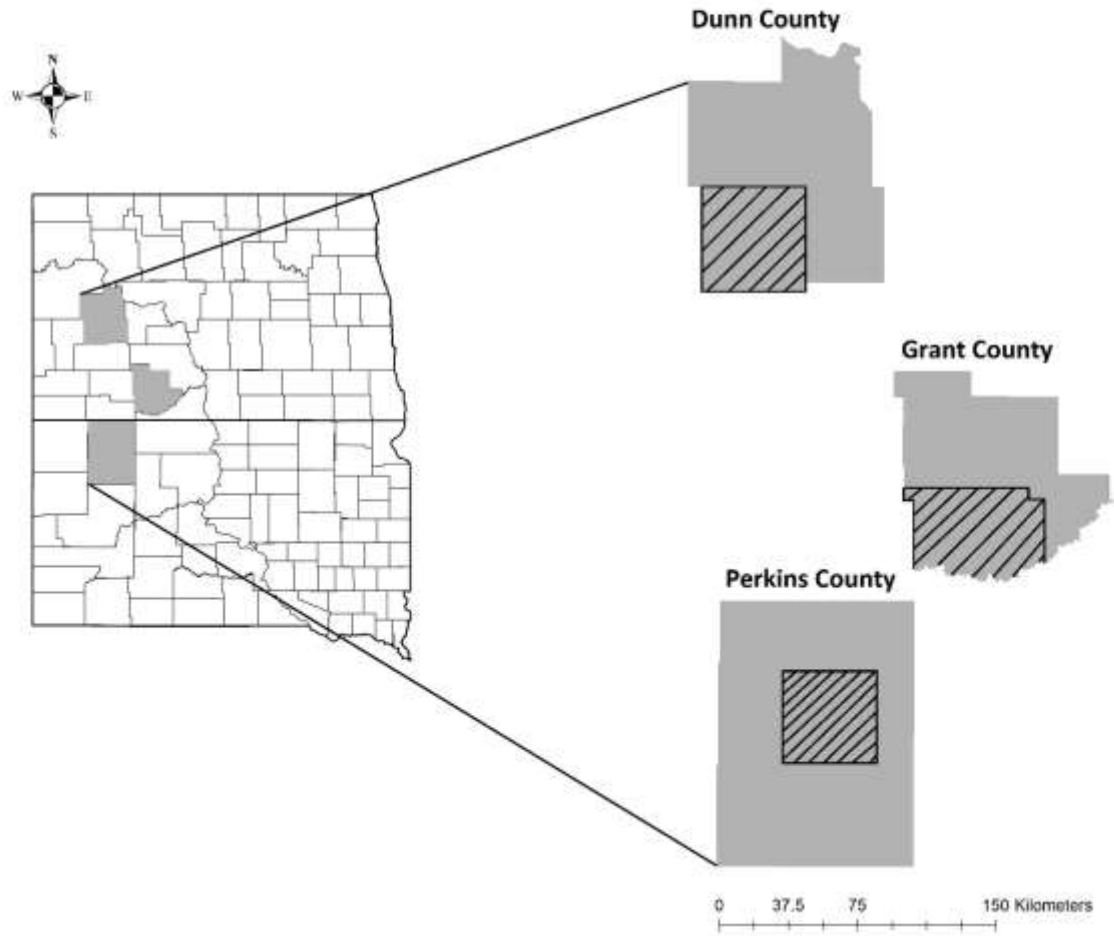

Figure 2-1. Study areas where adult female white-tailed deer were captured and radio-collared in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA. Dashed lines indicate deer capture areas within each study area.

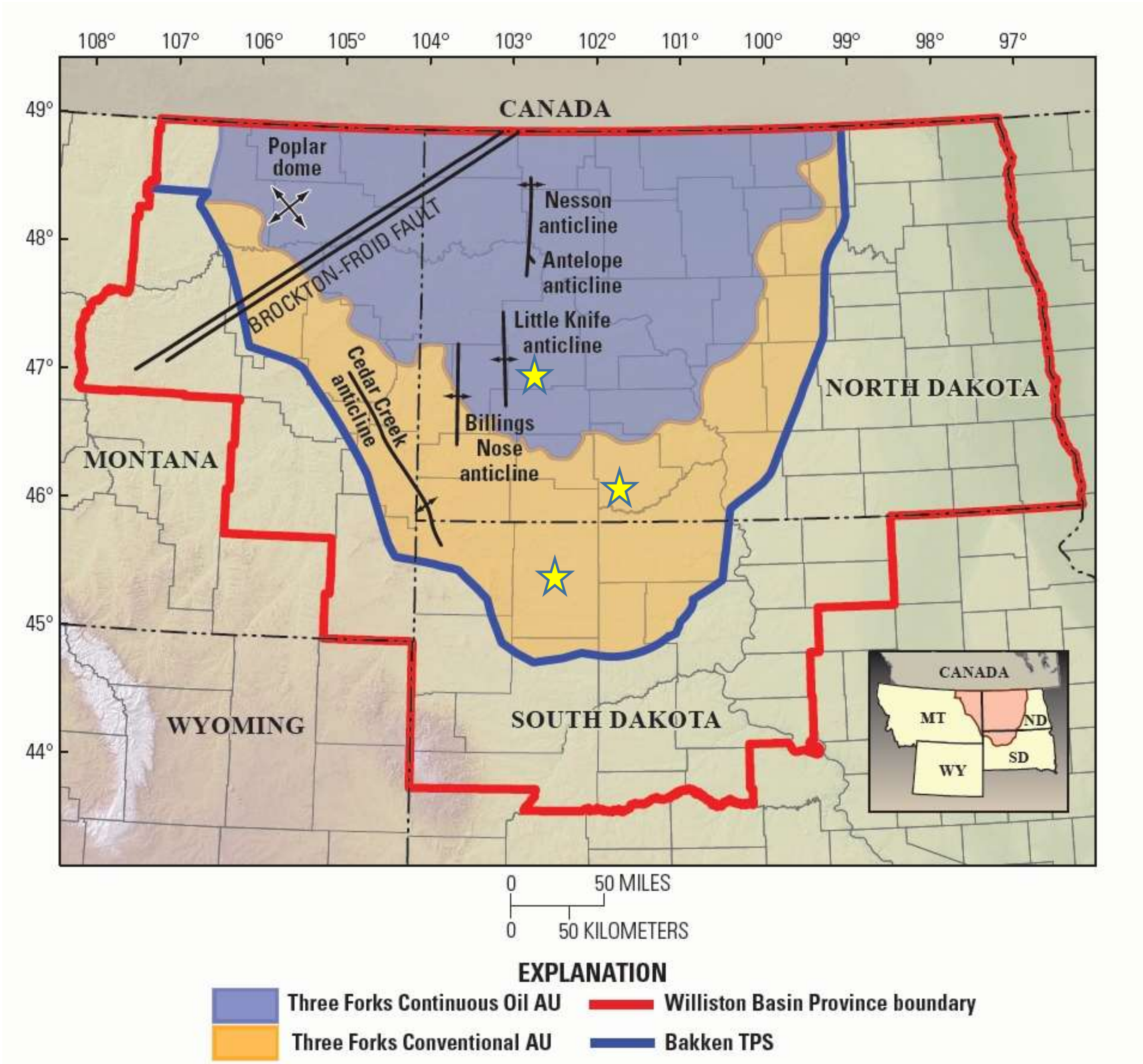

Figure 2-2. Bakken-Three Forks Formations in the Williston Basin in the Northern Great Plains (U. S. Geological Survey 2013). Yellow stars denote study areas.

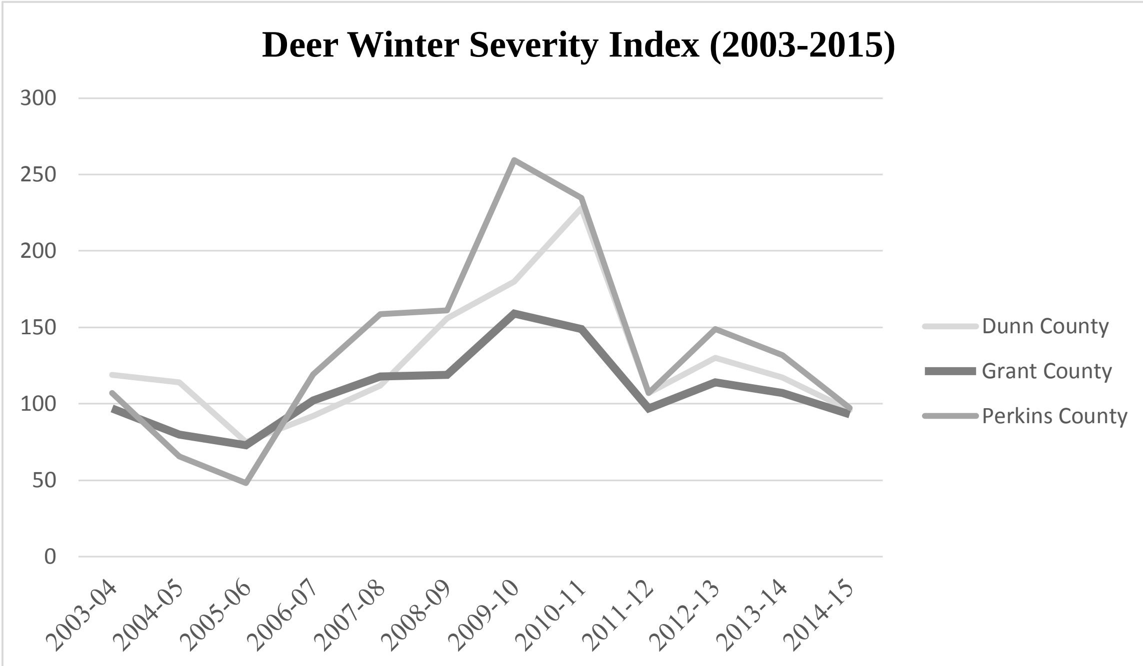

Figure 2-3. Deer winter severity indices (DWSI) plotted against the mean DWSI for southwestern North Dakota and northwestern South Dakota, USA. In North Dakota, we assigned one point for each day mean temperature was ≤ - 7° C and an additional point for each day snow depth was ≥35.0 cm (W. F. Jensen, North Dakota Game and Fish, pers. comm., Unpublished Data). South Dakota DWSI was regressed against Grant County DWSI to make estimates comparable.

CHAPTER 3: ENERGY DEVELOPMENT IMPACTS ON WHITE-TAILED DEER SURVIVAL IN THE DAKOTAS

ABSTRACT Oil and natural gas development has expanded in recent decades and impacts on white-tailed deer (*Odocoileus virginianus*) survival and human-related mortality are unknown. Our objective was to assess annual and seasonal survival rates for female white-tailed deer in western North Dakota and northwestern South Dakota. We also compared white-tailed deer survival among control and treatment (i.e. oil and natural gas development) study areas. Dunn County, North Dakota, an area influenced by energy development, and Grant County, North Dakota, and Perkins County, South Dakota, areas not currently impacted by energy development during 2014 and 2015 represented areas under study. We hypothesized that female survival in our energy development area would be lower than in other areas due to increased vehicle traffic and other anthropogenic activities related to the presence of oil and natural gas development. We captured and radio-collared 165 female white-tailed deer across our three study areas. We estimated survival rates based on study area (Dunn, Grant and Perkins counties) and season (Post-hunt, January-April; Pre-hunt, May-August; and Hunt, September-December). Dunn County displayed the highest annual survival rate (96%, SE = 0.02) followed by Perkins (93%, SE = 0.03) and Grant (75%, SE = 0.06) counties. Seasonal survival was highest (100%) during Pre-hunt and Post-hunt periods in Dunn and Perkins counties. Seasonal survival was lowest during Post-hunt in Grant County (87%). Our results indicate there were no detectable negative impacts of oil and natural gas development on female white-tailed deer survival. Other, density-dependent factors likely explained differences in

survival across study areas; nevertheless, further monitoring is needed to determine long-term responses of white-tailed deer to energy development.

INTRODUCTION

Oil and natural gas development has expanded in the western United States and has impacted a number of wildlife species (Dyer et al. 2001, Hebblewhite et al. 2008, Wiseman 2009). For example, decreases in sage grouse (*Centrocercus urophasianus*, Walker et al. 2007), caribou (*Rangifer tarandus,* Dyer et al. 2001), pronghorn (*Antilocapra americana*), and mule deer (*Odocoileus hemionus*, Sawyer et al. 2005) population densities have been observed in oilfield areas. Mule deer also have shown no evidence of acclimation to oil well pads and development and avoided areas close to oil well pads (Sawyer et al. 2006). Bottlenecks have been documented in pronghorn migration corridors due to regional oil development (Sawyer et al. 2005, Beckmann et al. 2008). Elk (*Cervus elaphus*) have been documented avoiding roads and areas of human activity (Rost and Bailey 1979, Edge 1982) and alter home ranges when oil wells are installed (Van Dyke and Klein 1996). Oil and gas development also fragments habitat and increases edge habitat, which can increase nest predator success rates (Kuehl and Clark 2002, Batary and Bladi 2004).

White-tailed deer movements, habitat use, and survival have generally been well documented in the Northern Great Plains (western Minnesota, DelGiudice et al. 2002; Brinkman et al. 2004; eastern North Dakota, Smith et al. 2006; and South Dakota, Grovenburg et al. 2011), but comparable information has not been collected in the western Dakotas except for in the Black Hills region of South Dakota (DePerno et al. 2000). Lack of information on white-tailed deer in the western Dakotas is concerning because of the potential negative impacts of increasing oil and natural gas development on this species. North Dakota Game and Fish Department uses reported mule deer responses to energy development as a surrogate for potential impacts on white-tailed deer, which assumes response is equivalent for the two species (Dyke et al. 2011).

Our objective was to estimate survival rates (annual and seasonal) and to investigate cause-specific mortality for female white-tailed deer in western North Dakota and northwestern South Dakota, USA. We were specifically interested in assessing if oil and natural gas development affected survival rates and cause-specific mortality of white-tailed deer. We hypothesized that oil and natural gas development would reduce female white-tailed deer survival because individuals would be disturbed by noise and traffic (Stankowich 2008), exposed to increased vehicle collisions (Johnson 1980, Frair 2005), and need to travel to less disturbed areas away from well sites (Sawyer et al. 2006, Van Dyke et al. 2012). Therefore, we predicted that oil and natural gas development would negatively impact female white-tailed deer survival.

STUDY AREA

We investigated female white-tailed deer survival rates and cause-specific mortality in Dunn and Grant counties, North Dakota and Perkins County, South Dakota (Figure 3-1) during 2014 and 2015. Counties were located in the Northwestern Great Plains Level III Ecoregion (Bryce et al. 1998) with each study area located in the Williston Basin Geological Formation (U. S. Geological Survey 2013, Figure 3-2).

In Dunn County, we focused deer capture in a 1,492 km^2 area in the southwestern portion of the county. Grasslands, cropland, and forested areas in Dunn County comprised 60, 20, and 9% of the land cover, respectively (Cropland Data Layer, U. S. Department of Agriculture 2015) and estimated minimum white-tailed deer density, based upon winter aerial surveys, was 1.0 deer/km^2 in 2011 (Stillings et al. 2012). Thirty-year mean annual precipitation in Dunn County was 41.4 cm and thirty-year mean monthly temperature ranged from -15.1^{o}C to 29.3^{o}C (North Dakota State Climate Office 2016).

In Grant County, we focused deer capture in a 1,865 km^2 area in the southwestern portion of the county. Grasslands, cropland, and forested areas in Grant County comprised 68, 26, and 1% of the land cover, respectively (Cropland Data Layer, U. S. Department of Agriculture 2015) and estimated minimum winter white-tailed deer density was 1.8 deer/km^2 in 2011 (Stillings et al. 2012). Seven (1 white-tailed deer, 6 mule deer) deer tested positive for chronic wasting disease (CWD) in Grant County since 2009 (D. M. Groves, North Dakota Game and Fish Department, personal communication). Thirty-year mean annual precipitation in Grant County was 41.2 cm and thirty-year mean monthly temperature ranged from -14.4^{o}C to 29.7^{o}C (North Dakota State Climate Office 2016).

In Perkins County, we focused deer capture in a 1,492 km^2 area in the central portion of the county. Grasslands, cropland, and forested areas in Perkins County comprised 86, 11, and 0.01% of the land cover, respectively (Cropland Data Layer, U. S. Department of Agriculture 2015). White-tailed deer density was estimated at 1.2 ± 0.04 deer/km^2 during 2015 (K. Robling, South Dakota Department of Game, Fish and Parks, personal communication). Thirty-year mean annual precipitation in Perkins County was

44.9 cm and mean thirty-year monthly temperature ranged from -12.1^{o}C to 30.3^{o}C (North Dakota State Climate Office 2016).

Grasslands in this region were dominated by native mixed grassland prairie species such as western wheatgrass (*Pascopyrum smithii*), needle and thread (*Hesperostipa comata*), green needle grass (*Nassella viridula*), little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans,*), prairie junegrass (*Koeleria macrantha*), and reed canary grass (*Phalaris arundinacea*) (Sedivec et al. 2011). Introduced grasses include smooth brome (*Bromus inermis*), orchard grass (*Dactylis glomerata*), crested wheatgrass (*Agropyron* sp.), timothy (*Phleum pratense*), and Kentucky bluegrass (*Poa pratensis*) (Sedivec et al. 2011). Primary harvested crops included corn (*Zea mays*), wheat (*Triticum aestivum*), sunflowers (*Helianthus annuus*), and alfalfa (*Medicago sativa*) (Sedivec et al. 2011). Other crops included flaxseed (*Linum usitatissimum*), canola (*Brassica* sp.), soybeans (*Glycine max*), barley (*Hordeum vulgare*), safflower (*Carthamus tinctorius*), oats (*Avena sativa*), and Sudan grass (*Sorghum bicolor,* spp. *drummondii*) (Sedivec et al. 2011).

Oil and natural gas development was prevalent in North Dakota. For example, 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). High production levels ranked North Dakota second and thirteenth in the nation for crude oil and natural gas production, respectively, in 2014 (U. S. Department of Energy 2014). Currently, there are about 1,800 active oil wells in Dunn County producing approximately 64 million barrels of oil and 35 MCF of natural gas each year (Department of Mineral Resources Oil and Gas

Division 2016). Grant and Perkins counties capped and abandoned oil and natural gas wells by the 1980s due to low productivity (Department of Mineral Resources Oil and Gas Division 2016, South Dakota Department of Environment and Natural Resources 2016).

Recreational hunting season dates were similar across study areas and occurred from 4 September 2014 to 4 January 2015 and 4 September 2015 to 3 January 2016 in North Dakota. Recreational hunting occurred from 27 September 2014 to 15 January 2015 and 26 September 2015 to 15 January 2016 in South Dakota.

METHODS

We captured adult female (>1.5-year-old) white-tailed deer via helicopter net guns (Native Range Capture Services, Elko, NV, USA, 2014) from 24 February to 2 March, 2014. Helicopter crew members hobbled, blindfolded, and fitted individuals with a Very High Frequency (VHF) radio-collar and a Vaginal Implant Transmitter (VIT; Advanced Telemetry Systems, Inc., Isanti, MN, USA). We implanted VITs in a subset of females to aid in determining fawning habitat in each study area. We captured additional adult female white-tailed deer in Grant County via helicopter net guns (Quicksilver Air Inc., Peyton, CO, USA, 2015) on 14 February 2015. In 2015, the helicopter capture crew transported captured individuals below the helicopter in canvas transport bags to a processing site. We gave each individual 1 ml Banamine and 3 ml BO-SE (Selenium and Vitamin E, D. M. Grove, North Dakota Game and Fish Department, personal communication) and estimated age based on tooth wear before release. We censored all mortalities that occurred within 26-days post-capture regardless of ultimate cause of death to remove mortalities potentially related to capture stress (Beringer et al. 1996).

We drew 20 ml of blood from each radio-collared female via jugular venipuncture at the capture location or in 2015, the processing site. We allowed blood vials to warm to room temperature and clot before centrifugation. We separated serum from cells via pipette and placed serum in cryovial tubes and then sent samples to Bio Tracking, Inc. (Moscow, ID, USA) to determine pregnancy status. We estimated age at death from cementum annuli analysis (Matson's Laboratory, LLC, Milltown, MT, USA) using mean ± standard deviation. All handling methods followed the American Society of Mammalogists guidelines for mammal care and use (Sikes et al. 2016) and were approved by the South Dakota State University Institutional Animal Care and Use Committee (Approval No. 13-091A).

We located deer 1-3 times per week using aerial telemetry, omnidirectional whip antennas, and handheld telemetry equipment. We took 3-6 directional bearings using a magnetic compass and used LOCATE III software (Nams 2006) on Trimble Juno handheld GPS units (Trimble Navigation Limited, Sunnyvale, CA, USA). We removed estimated locations with 95% error ellipses ≥20 ha from analysis (Giuliano et al. 1999, Brinkman et al. 2005, Grovenburg et al. 2009). We investigated mortalities immediately after detecting a mortality signal and transported carcasses to the North Dakota Game and Fish Wildlife Laboratory in Bismarck, North Dakota, to confirm proximate cause of death. We recorded counts of vehicle-killed white-tailed deer to estimate vehicle collision mortalities (VCM) in each study area. Natural causes of mortality were disease, predation, and unknown mortalities. We classified hunter harvest and VCM as human-related mortalities.

We used camera scent-station surveys to estimate relative coyote (*Canis latrans*) abundance in April and May 2015. Within our three study sites, we selected areas that contained radio-collared female home ranges and comprised 17 sections (2.6 km^2). We selected two survey areas in Dunn County that included one area with and one area without oil and natural gas development. We used ArcGIS 10.3.1 (Esri 2015) to plot 30 random points using 1000 m buffers in each area (Burr 2014). We then selected 15 of the 30 random points based on landowner permission and distance to edge habitat (Burr 2014). We defined edge habitat as areas where grassland, cropland, trees/shrubs, and fences intersected.

We placed Covert Extreme Red 40 (Covert Scouting Cameras, Inc., Lewisburg, KY, USA) infrared field cameras over 50 m from active roads near the closest habitat edge and faced them north or south to reduce sun glare (Burr 2014). We placed cameras approximately 0.5 m above the ground on a metal stake about 10 m from a scent lure and removed vegetation for a clear line of sight between the camera and scent lure (Burr 2014). We used two types of scent lures during the survey to prevent predator acclimation (Burr 2014). We used fatty acid scent tablets (Pocatello Supply Depot, Pocatello, ID, USA) for the first 11 days and then Caven's "Violator 7" predator lure (Minnesota Trapline Products, Pennock, MN, USA) for the next 11 days. We placed the second predator lure inside a hollow golf ball on a wooden dowel staked above ground to give an olfactory stimulus in addition to the scent (Burr 2014). We replaced scent lures every 4 – 5 days and after precipitation events to prevent dilution. We replaced memory cards and batteries on the twelfth day. Cameras took 3 pictures 3 seconds apart when triggered and could not be retriggered for 5 minutes (Burr 2014).

Cameras were deployed 1 – 22 April 2015 in Dunn and Grant counties. Cameras were deployed 25 April – 16 May 2015 in active oil development in Dunn County. Survey dates were later in active oil development because we had 15 cameras available for use in each study area. We deployed cameras from 1 April to 11 May 2015 in Perkins County due to landowner permission issues; only four cameras followed scent lure protocol due to the inability to access camera scent-stations on private property.

We reviewed photos and identified meso-predators to the species-level. We tallied the number of coyotes and used that information to calculate a scent-station index (SSI) for each of the four survey locations (Linhart and Knowlton 1975; Diefenbach et al. 1994). We calculated SSI using the following formula (Linhart and Knowlton 1975, Diefenbach et al. 1994).

$$\mathrm{SSI} = \left[\frac{\#\ \text{predator visits}}{\#\ \text{station nights}}\right] * 1000$$

We calculated Deer Winter Severity Indices (DWSI, Brinkman et al. 2005) for the 2012-2013 and 2013-2014 winters. In North Dakota, one point was awarded each day the mean temperature was ≤-7° C. The index received an additional point for each day mean snow depth was ≥35.0 cm (Brinkman et al. 2005) from November to April. In South Dakota, we calculated the annual Winter Severity Index (WSI) from the sum of mean monthly WSI values from November to April using the following formula (K. Robling, South Dakota Department of Game, Fish and Parks, personal communication):

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

We regressed Perkins County DWSI against Grant County DWSI to adjust South Dakota estimates. Winters were considered mild when index values were below 50, moderate when index values were between 50 and 100, and severe when index values were above 100.

We summarized weekly female mortality using telemetry data. We estimated annual and seasonal survival rates using the Kaplan-Meier method (Kaplan and Meier 1958) adapted for staggered entry (Pollock et al. 1989) in Program MARK version 6.0 (White and Burnham 1999, Cooch and White 2016). We used study area to assess variation in survival related to oil and natural gas development. We assessed survival with respect to study area, season, and time. We calculated seasonal survival rates for three time periods during 2014 and 2015: Post-hunt (January–April), Pre-hunt (May–August), and Hunt (September–December). We considered variables significant when 95% confidence intervals (CI) of beta estimates did not include zero (Cooch and White 2016).

RESULTS

We captured and radio-collared 50 adult female white-tailed deer via helicopter net gun and inserted VITs in 30 females captured in Dunn, Grant, and Perkins counties during February 2014. We captured and radio-collared 15 additional female white-tailed deer and placed VITs in 13 of those adult females due to high mortality in Grant County during February 2015. Overall pregnancy rate for all study areas was 96% ($n = 165$). Radio-collared white-tailed deer moved an average distance of 5.5 ± 4.6 km ($n = 100$) during 2014 from capture locations to summer home ranges located in Adams, Billings, Dunn, Grant, Hettinger, McKenzie, Sioux, and Stark counties, North Dakota and Perkins

County, South Dakota. We observed 7 total capture related mortalities during 2014 and 2015 capture events and removed those individuals from analyses. We were unable to locate one individual after December 2014 and therefore, censored it from the 2015 Perkins County analysis.

We documented 31 (20%) mortalities during the study (Table 3-1). Average age at death was 4.7 ± 2.0 years (n=16). Natural causes accounted for 23 (74%) mortalities and human-related causes accounted for 8 (26%) mortalities. Predation and hunter harvest were leading causes of natural and human-related mortalities, respectively. Grant County displayed the highest mortality with 21 (68%) mortalities (Table 3-1). Five (24%) mortalities were human-related and sixteen (76%) were from natural causes. Perkins County had 6 (19%) mortalities during the study (Table 3-1). Three (50%) mortalities were from natural causes and 3 (50%) were from human-related causes. Dunn County exhibited the lowest mortality of all study sites with all 4 (13%) mortalities attributed to natural causes (Table 3-1). No mortalities tested positive for CWD. We counted 7, 4, and 29 vehicle-killed white-tailed deer in Dunn, Grant, and Perkins counties, respectively.

Post-hunt, Pre-hunt, and Hunt time periods included 10 (32%), 4 (13%), and 17 (55%) mortalities, respectively (Table 3-2). Natural causes accounted for all 10 post-hunt mortalities. We observed 90% of Post-hunt mortalities during March and April (4 in 2014; 5 in 2015) after North Dakota Game and Fish Department conducted aerial deer surveys. Pre-hunt mortalities included 3 (75%) natural mortalities and 1 (25%) VCM. Mortalities that occurred during the hunt period included 10 (58.8%) natural mortalities and 7 (41.2%) human-related mortalities.

Model selection indicated that S (season+area) was the best approximating model for estimating female survival (w_i = 0.99, Table 3-3). This model indicated that survival of deer varied by study area and season; there was a difference in deer survival between oil development and non-development areas. Oil development (Dunn) had similar deer survival (96%, SE = 0.02) compared to Perkins (93%, SE = 0.03) County and higher deer survival than Grant (75%, SE = 0.06) County. Post-hunt seasons in Dunn and Perkins counties displayed the greatest survival of deer (99 and 100%, respectively, SE = 0.00, Table 3-4). Pre-hunt seasons in Grant County displayed the greatest survival of deer (98%, SE = 0.01, Table 3-4). Hunt seasons displayed the lowest survival of deer for all three study areas (97, 88, and 95%, SE = 0.04, 0.02, 0.03, respectively, Table 3-4). Noteworthy time periods included Dunn and Grant counties Post-hunt (β = 7.12, 95% CI = 5.16 to 9.08 and β = -2.30, 95% CI = -4.37 to -0.23, respectively) and Grant County Hunt (β = -2.18, 95% CI = -4.24 to -0.12). Survival of deer also varied annually between study areas. Annual survival of deer was greatest for Dunn County in 2015 (96%) and was the lowest for Grant County in 2014 (75%, Table 3-5).

Coyote relative abundance varied among the 4 survey locations. We observed 64 coyote detections at 30 stations among our 4 survey locations. Calculated SSI for the 4 locations were 62 in Dunn oil development, 69 in Dunn, 15 in Grant, and 36 in Perkins (Table 3-6).

The U. S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA APHIS) conducts annual coyote culling via aerial gunning in the three study areas. During 2014, APHIS removed 39, 173, and 263 coyotes in Dunn, Grant, and Perkins counties, respectively, and during 2015, removed 28, 162, and 292 coyotes in

Dunn, Grant, and Perkins counties, respectively (P. Mastrangelo, USDA APHIS, personal communication). Before our camera scent-stations were deployed in 2015, APHIS removed 14, 108, and 55 coyotes from Dunn, Grant and Perkins counties, respectively (P. Mastrangelo, USDA APHIS, personal communication).

Calculated DWSI was similar across study areas. Different equations were used to calculate DWSI in each state, therefore, we used a linear regression model to calculate predicted DWSI for Perkins County using Grant County data. In Dunn County, the average DWSI for the winters of 2013-2014 and 2014-2015 was 117 and 96, respectively (Figure 3-3). In Grant County, the average DWSI for the winters of 2013-2014 and 2014-2015 was 107 and 93, respectively (Figure 3-3). In Perkins County, the average DWSI for 2013-2014 and 2014-2015 winters was 132 and 97, respectively (Figure 3-3).

DISCUSSION

Our results do not support our prediction that oil and natural gas development would negatively affect female white-tailed deer survival. Annual survival rates for female white-tailed deer in Dunn County (96%; oil and natural gas development) were similar to survival rates in Perkins County (93%) but were higher than survival rates in Grant County (75%). Higher survival rates in Dunn County could indicate that the impacts of oil and natural gas development in western North Dakota may have been experienced prior to the start of our study. The literature is inconsistent in determining oil and natural gas development impacts on ungulate species. Christie et al. (2015) found that pronghorn abundance in North Dakota was negatively affected by high road and oil well density and energy development. Mule deer and elk have been documented shifting habitat use to less-suitable habitat due to energy development (Powell 2003, Sawyer et al. 2006); yet, Walter et al. (2006) determined that elk movements and nutrition were not adversely affected by wind-power development. Ciuti et al. (2014) reported the potential interaction of habitat fragmentation from energy development roads and increased coyote predation on mule deer fawns. However, Wyoming pronghorn populations showed no significant difference in survival rates between developed and undeveloped areas because habitat loss from development was not decreasing winter carrying capacity (Beckmann et al. 2008).

Forage quality and availability could have influenced deer densities in our three study areas (DeYoung 2011). Deer density varied by study area, and Grant County displayed the highest deer density (1.8 deer/km^2) compared to similar density in Perkins County (1.2 ± 0.04 deer/km^2) and Dunn County (1.0 deer/km^2). Higher deer density could have caused intraspecific competition for food resources or the amount of quality forage could have limited deer density in our study areas (DeYoung 2011). We hypothesize that lower deer densities in Dunn County allowed for adequate availability of quality forage and cover away from development areas, decreasing mortality related to oil and natural gas development. A long-term study in the region would clarify density dependent and independent factors impacting deer populations.

Our reported survival rates for Grant County support previous studies while Perkins County displayed higher survival rates and was inconsistent with the literature. Female white-tailed deer survival rates were 80% in central North Dakota (Smith et al. 2006), 76% in eastern South Dakota (Grovenburg et al. 2011), 56% in the Black Hills region of South Dakota (DePerno et al. 2000), 77% in southwestern Minnesota (Brinkman et al. 2004), and 63% in eastern Montana (Dusek et al. 1992). We expected lower survival rates in Grant County compared to Perkins County because oil and natural gas development was absent, and we expected a CWD impact on deer in Grant County. Perkins County had more agricultural land compared to other study areas (Cropland Data Layer, U.S. Department of Agriculture 2015), and we focused deer capture in central Perkins County where agriculture dominates the landscape. Female white-tailed deer in Perkins County may have benefited from ample food and summer cover provided by cropland (Nixon et al. 1991, Brinkman et al. 2004, Heffelfinger 2011), which allowed females to be in better body condition to survive severe winter weather and other natural causes of mortality.

We expected the highest numbers of VCMs in Dunn County due to high traffic volume related to oil and natural gas development. Dunn County deer density was the lowest in North Dakota, which suggests that we would observe less VCMs as compared to other areas; VCMs were highest in Perkins County. Species such as elk (Rost and Bailey 1979, Bromley 1985), mule deer (Rost and Bailey 1979, Freddy et al. 1986, Sawyer et al. 2006), and pronghorn (Landon et al. 2003) display road avoidance behavior in areas of energy development. Powell (2003) also observed elk avoiding well sites and roads long after construction was completed. Therefore, we hypothesize that even with low deer densities, female white-tailed deer have learned how to survive and avoid high traffic in the energy development area in Dunn County.

Predation was the leading cause of mortality in Grant County. Our coyote SSI indicated coyote abundance did not influence survival. Grant County SSI was the lowest, but 43% of predation mortalities compared to 25% in Dunn and 17% in Perkins counties. This suggests a disproportionate amount of predation may have occurred in Grant

County. We observed similar coyote SSI in non-development and development camera scent-station survey areas in Dunn County. Our results do not support those of Burr (2014), who reported lower predator occupancy in high energy development. Oil and natural gas development in Dunn County could be below densities that negatively impact coyote abundance. Other factors, such as weather and habitat conditions, could be confounding predation effects in Grant County (Bergman et al. 2015).

Seasonal survival rates (Post-hunt, Pre-hunt, and Hunt) were similar for Dunn and Perkins counties and support previous research reported in central North Dakota (Post-hunt = 84%, Pre-hunt = 92%, and Hunt = 84%, Schaffer 2013), eastern South Dakota (97, 97, 80%, Grovenburg et al. 2011), and southwestern Minnesota (95, 100, 80%, Brinkman et al. 2004). In all study areas during 2014, DWSI was slightly above severe, and the 2015 DWSI was just below severe. Post-Hunt mortalities observed were nearly equivalent between years providing evidence that winter severity was similar during both winter seasons. High Pre-hunt survival in Dunn and Perkins counties compared to Grant County may be attributed to high forage quality and availability, abundant cover, and minimal human activity (Nixon et al. 1991, Brinkman et al. 2004).

Despite having the lowest Post-hunt and Hunt time period survival during our study, survival of deer in Grant County still fell within the reported Post-hunt, Pre-hunt, and Hunt time period survival estimates in central North Dakota (84, 92, 84%, Schaffer 2013), eastern South Dakota (97, 97, 80%, Grovenburg et al. 2011), and southwestern Minnesota (85, 100, 80%, Brinkman et al. 2004). We observed more Post-hunt mortalities in Grant County than in Dunn or Perkins counties. Females are more likely to face a higher mortality risk when nutritionally taxed due to poor-quality forage during fall and winter and limited forage in early spring (DePerno et al. 2000). Higher spring mortality in Grant County compared to Dunn and Perkins counties may be attributed to limited escape cover, poor forage conditions during winter, and a higher deer density leading to lower female body condition (DePerno et al. 2000).

Contrary to other studies in the region (Brinkman et al. 2004, DelGiudice et al. 2002, Grovenburg et al. 2011), hunter harvest was not the leading cause of mortality in our study despite the fact that Hunt time periods displayed the lowest survival for all study areas. Antlerless deer tag availability decreased in western North and South Dakota during 2014 and 2015 (Huxoll 2015, Stillings et al. 2016) however, many hunters choose to shoot males over females if given the opportunity (Jenks et al. 2002) and may have been selecting against harvesting a radio-collared deer. Thus, our observations may not have captured the typical extent of hunting mortality for female white-tailed deer (Magle et al. 2012). We observed 59% of mortalities in Hunt time periods from natural mortality factors including predation and disease (epizootic hemorrhagic disease, grain overload) suggesting that potential nutritional deficiencies are subjecting females to other causes of mortality.

Oil and natural gas development did not have a detectable negative impact on female white-tailed deer survival in the western Dakotas and therefore, mule deer are not an accurate surrogate for energy development impacts on white-tailed deer. White-tailed deer are an adaptive and opportunistic species that have benefited from anthropomorphic landscape changes (Nixon et al. 1991, Brinkman et al. 2004, Ballard 2011). Other species of ungulates and nongame species may respond differently to oil and gas development in the region. Sage grouse populations (Riley et al. 2012) and pronghorn movements

(Christie et al. 2015) have been documented as negatively affected by fencing, vehicle collisions, and well density in energy development areas. Additional research in high and low oil and natural gas development areas with similar deer densities could further clarify any impacts on white-tailed deer. Long-term studies are important to track trends in populations and to identify potential lags in response to oil and natural gas development (Beckmann et al. 2008).

MANAGEMENT IMPLICATIONS

We report high female survival in oil and natural gas development areas and therefore, development did not have a detectable impact on female survival in Dunn County. Our findings could be related to the amount of quality habitat available and lower deer density in Dunn County compared to that in our other study areas. Wildlife managers should continue to provide adequate habitat in oil and natural gas development areas to provide individuals with cover and resources while avoiding development areas, especially during winter. Because female survival in Grant County was similar to survival reported elsewhere for white-tailed deer, it is reasonable to believe that female survival in that area was relatively healthy, and habitat improvements may increase survival to similar levels observed in Dunn and Perkins counties. Conducting future habitat analysis will assess differences in forage quality and availability among study areas.

LITERATURE CITED

Ballard, W. 2011. Predator-Prey Relationships. Pages 251-286 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, FL, USA.

Batary, P., and A. Baldi. 2004. Evidence of an edge effect on avian nest success. Conservation Biology 18:389-400.

Beckmann, J. P., K. M. Berger, J. K. Young, and J. Berger. 2008. Wildlife and energy development: pronghorn of the Upper Green River Basin – year 3 summary. Wildlife Conservation Society, Bronx, NY. <http://www.wcs.org/yellowstone> Accessed 14 June 2016.

Bergman, E. J., P. F. Doherty, Jr., G. C. White, and A. A. Holland. 2015. Density dependence in mule deer: a review of evidence. Wildlife Biology 21:18-29.

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

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

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

Bromley, M. 1985. Wildlife management implication of petroleum exploration and development in wildland environments. U. S. Forest Service, Intermountain Research Station, Ogden, Utah, USA.

Bryce, S. J., M. Omernik, D. E. Pater, M. Ulmer, J. Schaar, J. Freeouf, R. Johnson, P. Kuck, and S. H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. (Map poster). U.S. Geological Survey, Jamestown, ND.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach, 2nd edition. Springer-Verlag New York, Inc., New York, NY, USA.

Burr, P. C. 2014. Impacts of gas and oil development on sharp-tailed grouse (*Tympanuchus phasianellus*) nest success and predator dynamic in western North Dakota. Thesis, University of North Dakota, Grand Forks, USA.

Christie, K. S., W. F. Jensen, J H. Schmidt, M.S. Boyce. 2015. Long-term changes in pronghorn abundance index linked to climate and oil development in North Dakota. Biological Conservation 192:445-453.

Cooch, E., and G. C. White. 2016. Program Mark: a gentle introduction. Sixteenth edition. Department of Natural Resources, Cornell University, Ithaca, NY, USA.

Ciuti, S., W. F. Jensen, S. E. Nielsen, and M. S. Boyce. 2014. An evaluation of historical mule deer fawn recruitment in North Dakota. Report prepared for North Dakota Game and Fish Department.

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

Department of Mineral Resources [DMR] Oil and Gas Division. 2016. DMR Homepage. <https://www.dmr.nd.gov/> Accessed 14 June 2016.

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

DeYoung, C. A. 2011. Population dynamics. Pages 147-180 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Diefenbach, D. R., M. J. Conroy, R. J. Warren, W. E. James, L. A. Baker, and T. Hon. 1994. A test of scent-station survey technique for bobcats. Journal of Wildlife Management 58:10-17.

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

Dyke, S., D. Fryda, D. Kleyer, J. Williams, B. Hosek, W. Jensen, S. Johnson, A. Robinson, F. Ryckman, B. Stillings, M. Szymanski, S. Tucker, and B. Wiedmann. 2011. Potential impacts of oil and gas development on select North Dakota natural resources; a report to the director. North Dakota Game and Fish Department.

Dyer, S., J. O'Neill, S. Wasel, and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. Journal of Wildlife Management 65: 531-542.

Edge, W. 1982. Distribution, Habitat Use, and Movements of Elk in Relation to Roads and Human Disturbances in Western Montana. University of Montana. Missoula, MT.

Frair, J. L. 2005. Survival and movement behaviour of resident and translocated wapiti (*Cervus elaphus*): implications for their management in west-central Alberta, Canada. University of Alberta. Edmonton, Alberta, Canada.

Freddy, D. J., W. M. Bronaugh, and M. C. Fowler. 1986. Responses of mule deer to disturbance by persons afoot and snowmobiles. Wildlife Society Bulletin 14:63-68.

Giuliano, W. M., S. Demarais, R. E. Zaiglin, and M. L. Sumner. 1999. Survival and Movements of orphaned white-tailed deer fawns in Texas. Journal of Wildlife Management 63:570-574.

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

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

Hebblewhite, M. 2008. A literature review of the effects of energy development on ungulates: Implications for central and eastern Montana. Report prepared for Montana Fish, Wildlife and Parks, Miles City, MT.

Heffelfinger, J. R. 2011. Taxonomy, evolutionary history, and distribution. Pages 3-39 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Huxoll, C. 2015. 2015 Big game harvest projections. Game Report No. 2016-02. South Dakota Game, Fish and Parks, Pierre, South Dakota, USA.

Jenks, J. A., W. P. Smith, and C. S. DePerno. 2002. Maximum sustained yield harvest versus trophy management. Journal of Wildlife Management 66:528-535.

Johnson, B. 1980. Response of elk during calving to oil gas drilling activity in Snider Basin, Wyoming, Wyoming Game and Fish Department.

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

Kuehl, A. K., and W. R. Clark. 2002. Predator activity related to landscape features in northern Iowa. Journal of Wildlife Management 66:1224-1234.

Landon, D. M., P. R. Krausman, K. K. G. Koenin, and L. K. Harris. 2003. Pronghorn use of areas with varying sound pressure levels. Southwestern Naturalist 48:725-728.

Linhart, S. B., and F. F. Knowlton. 1975. Determining the relative abundance of coyotes by scent station lines. Wildlife Society Bulletin 3:119-124.

Magle, S. B., J. C. Chamberlin, N. E. Matthews. 2012. Survival of white-tailed deer in Wisconsin’s Chronic Wasting Disease zone. Northeastern Naturalist 19:67-76.

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

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

North Dakota State Climate Office. 2016. Monthly station normal of temperature, precipitation, and heating and cooling degree days 1981-2010. <https://www.ndsu.edu/ndsco/data/30yearaverage/#c343059> Accessed 12 July 2016.

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

Powell, J. 2003. Distribution, habitat use patterns, and elk response to human disturbance in the Jack Marrow Hills, Wyoming. M.S. Thesis, University of Wyoming, Laramie, USA.

Riley, T. R., E. M. Bayne, B. C. Dale, D. E. Naugle, J. A. Rodgers, and S. C. Torbit. 2012. Impacts of crude oil and natural gas developments on wildlife and wildlife habitat in the Rocky Mountain region. Technical Review prepared for The Wildlife Society, Bethesda, MD.

Rost, G. and J. Bailey. 1979. Distribution of mule deer and elk in relation to roads. Journal of Wildlife Management 43:634-641.

Sawyer, H., R. Nielson, D. Stickland, and L. McDonald. 2005. Mule Deer Study (Phase II): Long-term Monitoring Plan to Assess Potential Impacts of Energy Development on Mule Deer in the Pinedale Anticline Project Area. Western Ecosystems Technology, Inc., Cheyenne, WY.

Sawyer, H., R. Nielson, F. Lindzey, and L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. Journal of Wildlife Management 70:396-403.

Schaffer, B. A. 2013. An evaluation of life history parameters of white-tailed deer (*Odocoileus virginianus*) in North Dakota. Thesis, South Dakota State University, Brookings, USA.

Sedivec, K. K., T. D. A. Tober, W. L. Duckwitz, and J. R. Hendrickson. 2011. North Dakota State University Extension Service. Grass varieties for North Dakota. <https://www.ag.ndsu.edu/pubs/plantsci/hay/r794.pdf> Accessed 17 June 2016.

Sikes, R. S., and the Animal Care and Use Committee of the American Society of Mammalogists. 2016. 2016 Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy Volume 97, Issue 3, pages 663—688.

Smith, J. R, R. A. Sweitzer, and W. F. Jensen. 2006. Diets, movements, and consequences of providing wildlife food plots for white-tailed deer in central North Dakota. The Journal of Wildlife Management 71:2719-2726.

South Dakota Department of Environment and Natural Resources [DENR]. 2016. DENR homepage. http://denr.sd.gov>Accessed 14 June 2016.

Stankowich, T. 2008. Ungulate flight responses to human disturbance: a review and meta-analysis. Biological Conservation 141:2159-2173.

Stillings, B., B. Jensen, and J. Smith. 2012. Study No. C-I: Deer population studies. North Dakota Game and Fish Department. Bismarck, ND, USA.

Stillings, B., B. Jensen, and J. Smith. 2016. Study No. C-I: Deer population studies. North Dakota Game and Fish Department. Bismarck, ND, USA.

U. S. Department of Agriculture (USDA). 2015. USDA, National Agricultural Statistics Service (NASS), Cropland Data Layer. USDA, NASS Marketing and Information Services Office, Washington, D.C., USA.

U. S. Department of Energy. 2014. U. S. Energy Information Administration, Rankings: Total Energy Consumed per Capita, 2014. Energy Information Administration Office, Washington, D. C., USA.

U. S. Geological Survey (USGS). 2 May 2013. USGS releases new oil and gas assessment for Bakken and Three Forks Formations. <https://www2.usgs.gov/blogs/features/ usgs_top_story/usgs-releases-new-oil-and-gas-assessment-for-bakken-and-three-forks-formations/> Accessed 6 April 2016.

Van Dyke, F. and W. Klein. 1996. Response of elk to installation of oil wells. Journal of Mammalogy 77:1028-1041.

Van Dyke, F., A. Fox, S. M. Harju, M. R. Dzialak, L. D. Hayden-Wing, and J. B. Winstead. 2012. Response of Elk to habitat modification near natural gas development. The Journal of Environmental Management 50:942-955.

Walker, B. L., D. E. Naugle, and K. E. Doherty. 2007. Greater sage-grouse population response to energy development and habitat loss. Journal of Wildlife Management 71:2644-2654.

Walter, W. D., D. M. Leslie, Jr., and J. A. Jenks. 2006. Response of Rocky Mountain elk (*Cervus elaphus*) to wind-power development. American Midland Naturalist 156:363-375.

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

Wiseman, H. 2009. Untested waters: the rise of hydraulic fracturing in oil and gas production and the need to revisit regulation. Fordham Environmental Law Review 20:115-170.

Table 3-1. Cause-specific mortality for radio-collared adult female white-tailed deer in Dunn and Grant Counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

	Counties						
	Dunn		Grant		Perkins		
Cause	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**Total**
Harvest	0	0	3	1	0	2	6
Vehicle Collision	0	0	0	1	0	1	2
Unknown	1	1	1	3	0	1	7
Predation	1	0	5	4	0	1	11
Disease	0	0	3	0	1	0	4
Starvation	0	1	0	0	0	0	1
Total	2	2	12	9	1	5	31

Table 3-2. Seasonal cause-specific mortality for radio-collared adult female white-tailed deer in Dunn and Grant Counties, North Dakota and Perkins County, South Dakota during 2014 and 2015. Seasonal Intervals: Post-hunt (January -April), Pre-hunt (May-August), and Hunt (September -December).

	Intervals						
	Post-hunt		Pre-hunt		Hunt		
Cause	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**Total**
Harvest	0	0	0	0	3	3	6
Vehicle Collision	0	0	0	1	0	1	2
Unknown	0	3	1	0	1	2	7
Predation	4	3	0	1	1	2	11
Disease	0	0	1	0	3	0	4
Starvation	0	0	0	0	0	1	1
Total	4	6	2	2	8	9	31

Table 3-3. A *priori* models used to estimate adult female white-tailed deer survival in Dunn and Grant Counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

Models	AIC_c	ΔAIC_c	w_i	*K*	Deviance
S(season+area)[a]	414.43	0.00	0.99	7.00	400.42
S(area)	423.44	9.01	0.01	3.00	417.44
S(season)[a]	432.41	17.98	0.00	3.00	426.41
S(.)	437.67	23.25	0.00	1.00	435.67
S(t)	473.13	58.71	0.00	52.00	368.70

[a] Seasonal Intervals = Post-hunt (January -April), Pre-hunt (May-August), and Hunt (September -December).
AIC_c= Akaike's Information Criterion adjusted for small sample size (Burnham and Anderson 2002).
ΔAIC_c =Difference in AIC_c relative to minimum AIC.
w_i= Akaike weight (Burnham and Anderson 2002).
K=Number of parameters.

Table 3-4. Seasonal survival rates for radio-collared adult female white-tailed deer in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015. Seasonal Intervals: Post-hunt (January -April), Pre-hunt (May-August), and Hunt (September -December).

County	Season Interval	Estimate	SE	95% CI Lower	95% CI Upper
Dunn	Post-hunt	0.99	0.00	0.91	1.00
	Pre-hunt	1.00	0.00	1.00	1.00
	Hunt	0.97	0.04	0.90	0.99
Grant	Post-hunt	0.87	0.02	0.77	0.93
	Pre-hunt	0.98	0.01	0.91	0.99
	Hunt	0.88	0.02	0.79	0.93
Perkins	Post-hunt	1.00	0.00	1.00	1.00
	Pre-hunt	0.98	0.04	0.92	0.99
	Hunt	0.95	0.03	0.88	0.98

Table 3-5. Annual survival rates for radio-collared adult female white-tailed deer in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA during 2014 and 2015.

County	Year	Estimate	SE	95% CI Lower	95% CI Upper
Dunn	2014	0.95	0.02	0.88	0.98
	2015	0.96	0.02	0.88	0.98
Grant	2014	0.75	0.06	0.60	0.85
	2015	0.75	0.06	0.62	0.85
Perkins	2014	0.93	0.03	0.85	0.97
	2015	0.93	0.03	0.85	0.97

Table 3-6. Relative coyote abundance derived from camera scent-station surveys in April and May 2015 in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA.

Location	Coyote	SSI[a]
Dunn (Oil Development[b])	20	62
Dunn	21	69
Grant	5	15
Perkins	18	36

[a] Scent Survey Index = no. predator visits/no. operative station nights x 1,000
[b] 0.318 active oil wells/km^2

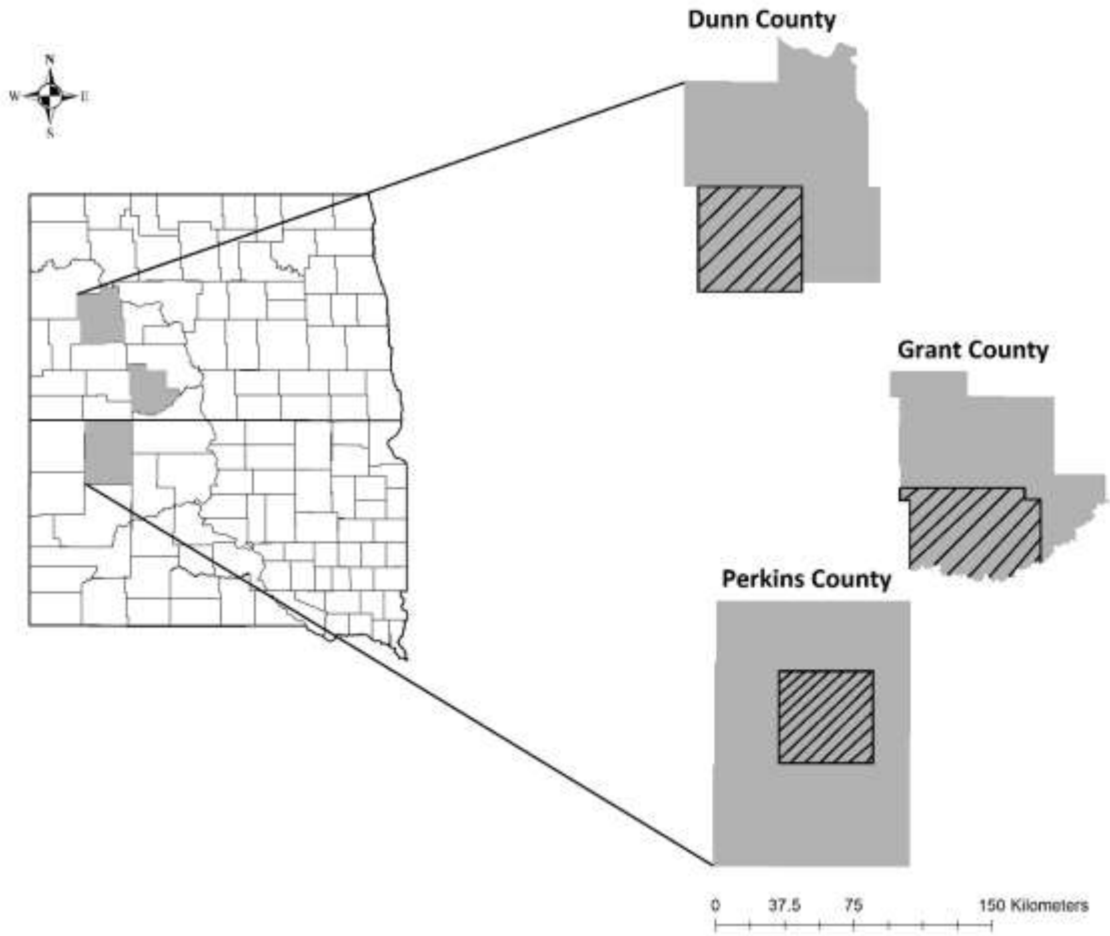

Figure 3-1. Study areas where adult female white-tailed deer were captured and radio-collared in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA. Dashed lines indicate deer capture areas within each study area.

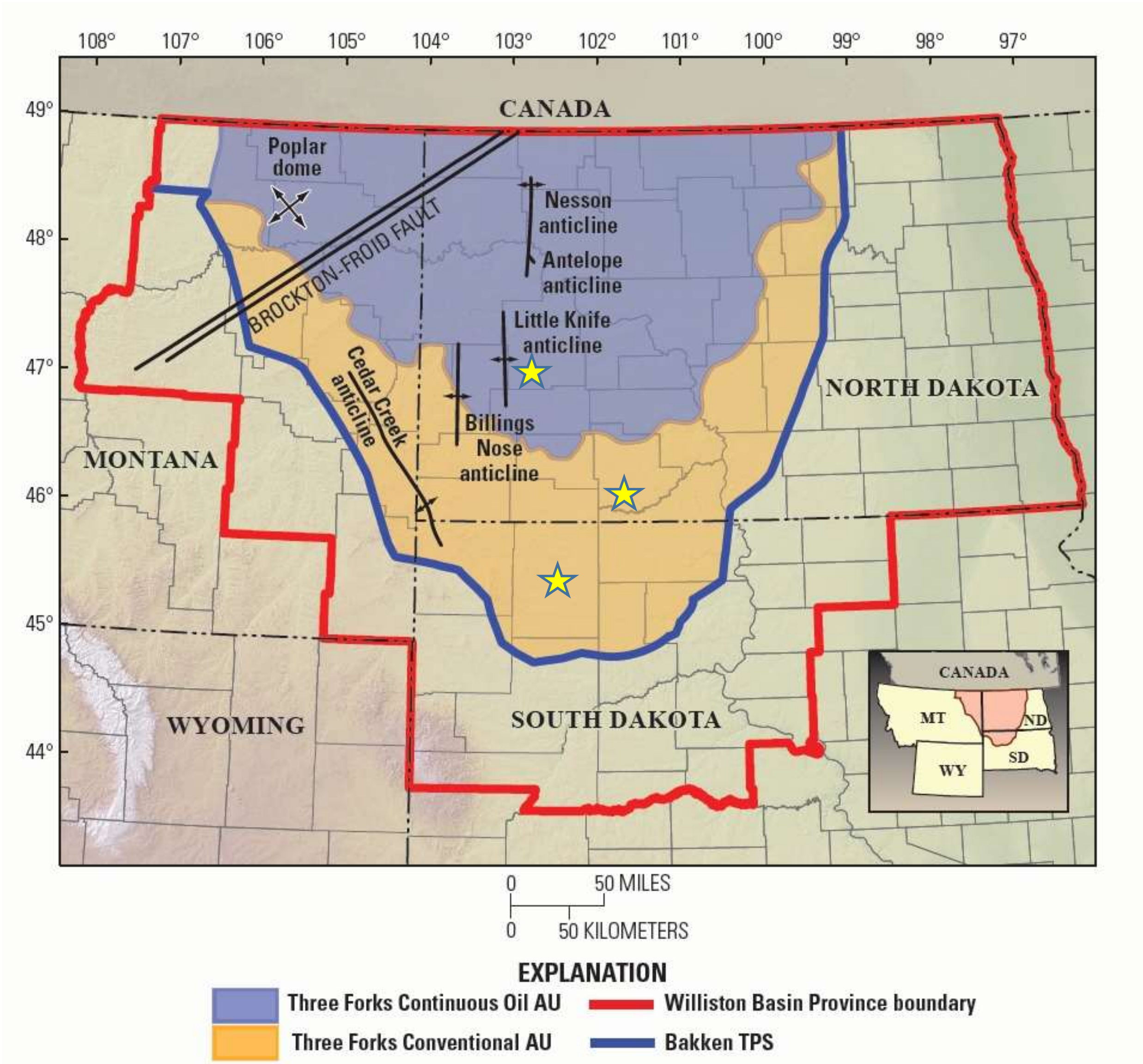

Figure 3-2. Bakken-Three Forks Formations in the Williston Basin in the Northern Great Plains (U.S. Geological Survey 2013). Yellow stars indicate deer capture areas.

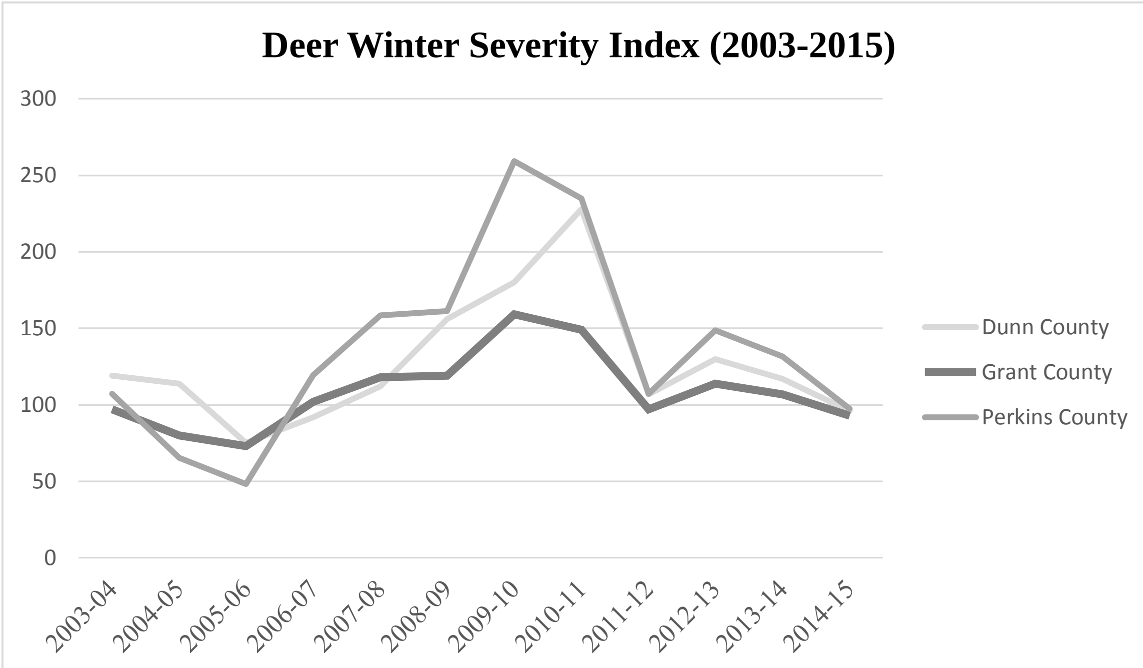

Figure 3-3. Deer winter severity indices (DWSI) plotted against the mean DWSI for southwestern North Dakota and northwestern South Dakota, USA. In North Dakota, we assigned one point for each day mean temperature was ≤ - 7° C and an additional point for each day snow depth was ≥35.0 cm (W. F. Jensen, North Dakota Game and Fish, pers. comm., Unpublished Data). South Dakota DWSI was regressed against Grant County DWSI to make estimates comparable.

CHAPTER 4: SEROLOGICAL SURVEY AND PATHOGEN EXPOSURE OF ADULT FEMALE WHITE-TAILED DEER IN THE WESTERN DAKOTAS

ABSTRACT Establishing baseline values for nutritional indices and pathogen exposure is necessary to monitor population health. However, little is known about white-tailed deer (*Odocoileus virginianus*) nutritional indices or livestock pathogen exposure in the Northern Great Plains. Increased oil and natural gas development in the region has negatively affected movements and survival of other wildlife species and also could impact white-tailed deer herd health. Our objective was to establish nutritional indices and assess exposure to pathogens for female deer in western North Dakota and northwestern South Dakota. Our study areas included Dunn County, North Dakota, an area influenced by energy development, and Grant County, North Dakota, and Perkins County, South Dakota, areas not impacted by energy development during 2014 and 2015. We hypothesized that energy development would negatively impact deer because individuals would potentially use sub-optimal habitat due to noise and traffic disturbance. We collected blood serum from 50 adult female deer from each of the three study areas during 2014 and from an additional 15 adult females in Grant County during 2015. We analyzed 2014 and 2015 Grant County blood samples separately because we found differences ($p<0.01$) between the majority of nutritional indices. We found differences in creatinine kinase, globulin, glucose, lactate dehydrogenase, magnesium, sodium, and total protein values ($p<0.034$) in blood serum among study areas during 2014. Pathogens with the highest antibody prevalence included West Nile Virus (WNV; 85%), epizootic hemorrhagic disease (48%), and malignant catarrhal fever (32%). We did not detect effects of energy development on deer health. We speculate that low sodium values and

high prevalence of WNV may be contributing to low neonate survival in Grant County. Serum differences among study areas could be attributed to differences in forage quality and availability. Differences in regional pathogen exposure are not well understood, and more research is needed to identify potential effects of WNV on deer health and survival.

INTRODUCTION

Evaluating nutritional indices and pathogen exposure rates are an important component of assessing wildlife health. Nutritional indices are used to detect disease and reproductive state of white-tailed deer (hereafter deer; *Odocoileus virginianus*; White and Cook 1974, Seal et al. 1981, Gill et al. 2001). Detecting antibodies also determines past exposure to livestock pathogens (bovine viral diarrhea virus (BVDV), bluetongue virus (BTV), epizootic hemorrhagic disease virus (EHD), etc.; Gilbert et al. 2013). Deer are sentinels for human and livestock related diseases (Gill et al. 1994, Wolf et al. 2008, Sherrill et al. 2012) and facilitate disease transmission (Roug et al. 2012, Myers et al. 2015). Therefore, monitoring health factors, establishing baseline nutritional indices, and pathogen exposure provide essential herd health information that may affect population trends (Myers et al. 2015).

Nutritional indices monitor trace element and metabolites in the blood stream to evaluate seasonal health and nutrition (Seal et al. 1981, DelGiudice et al. 1987, DeLiberto et al. 1989) and may be helpful when investigating forage nutritional value, reproduction, and survival (DelGiudice et al. 1991). Comprehensive regional analysis of nutritional indices are well documented in deer. Klinger et al. (1986) and White and Cook (1974) reported select blood characteristics of free-ranging deer in Kansas and southern Texas; respectively. DelGiudice et al. (1991) also investigated seasonal hematological differences of deer in northern Minnesota while Wolf et al. (2008) reported selenium values in female deer in southern Minnesota. Zimmerman (2004) investigated impacts of burning on nutritional indices of white-tailed deer and mule deer in the southern Black Hills. Seal et al. (1981) stressed the need for reference ranges for specific populations of white-tailed deer to accurately assess population health and to compare health across deer populations in the United States. However, there are no published nutritional indices for deer in western North and South Dakota.

Antibody prevalence only indicates previous exposure to an antigen and not current infection (Gilbert et al. 2013), but pathogen exposure can impact wildlife populations, domestic livestock, and human health (Wolf et al. 2008, Billinis 2012, Roug et al. 2012, Dubay et al. 2015). Reproductive effects of EHD and BTV could potentially impact ungulate populations as infection often occurs during the breeding season (Dubay et al. 2006). Humans can become infected with pathogens carried by deer such as *Anaplasma* and *Borrelia* (Wolf et al. 2008). Antibody prevalence in ungulate species is important in the west because livestock roam large tracts of land making disease transmission more likely than in areas where cattle are kept in confinement (Wolf et al. 2008). No information has been documented on livestock pathogen exposure rates in deer inhabiting the Dakotas.

Our objectives were to assess impacts of oil and natural gas development on white-tailed deer health. We assessed nutritional indices, compared nutritional indices among study areas and to reference ranges, and assessed pathogen exposure rates for adult female white-tailed deer in western North Dakota and northwestern South Dakota. Increased oil and natural gas development in in the western U. S. has impacted sage grouse (*Centrocercus urophasianus*, Walker et al. 2007), pronghorn (*Antilocapra americana*, Sawyer et al. 2005, Beckman et al. 2008), mule deer (*Odocoileus hemionus*, Sawyer et al. 2005, 2006), and elk (*Cervus elaphus*, Rost and Bailey 1979, Edge 1982) and also could impact white-tailed deer health. We hypothesized that oil and natural gas development would impact white-tailed deer because females would potentially move to sub-optimal habitat away from development areas (Sawyer et al. 2006, Van Dyke et al. 2012) and would increase movements due to noise and traffic disturbances (Stankowich 2008). Therefore, we predict that oil and natural gas development will negatively impact adult female deer health.

STUDY AREA

We assessed female deer nutritional indices and pathogen exposure in Grant and Dunn counties, North Dakota and Perkins County, South Dakota (Figure 4-1) during 2014 and 2015. The three study areas were located in the Northwestern Great Plains Level III Ecoregion (Bryce et al. 1998), and within the Williston Basin Geological Formation (U.S. Geological Survey 2013, Figure 4-2).

In Dunn County, we focused deer capture in a 1,492 km^2 area in the southwestern portion of the county. Grasslands, cropland, and forested areas in Dunn County comprised 60, 20, and 9% of the land cover, respectively (Cropland Data Layer, U. S. Department of Agriculture 2015) and estimated minimum white-tailed deer density, based upon winter aerial surveys, was 1.0 deer/km^2 in 2011 (Stillings et al. 2012). Thirty-year mean annual precipitation in Dunn County was 41.4 cm and thirty-year mean monthly temperature ranged from -15.1ºC to 29.3ºC (North Dakota State Climate Office 2016).

In Grant County, we focused deer capture in a 1,865 km^2 area in the southwestern portion of the county. Grasslands, cropland, and forested areas in Grant County comprised 68, 26, and 1% of the land cover, respectively (Cropland Data Layer, U. S. Department of Agriculture 2015) and estimated minimum winter white-tailed deer density was 1.8 deer/km^2 in 2011 (Stillings et al. 2012). Seven (1 white-tailed deer, 6 mule deer) deer tested positive for chronic wasting disease (CWD) in Grant County since 2009 (D. M. Groves, North Dakota Game and Fish Department, personal communication). Thirty-year mean annual precipitation in Grant County was 41.2 cm and thirty-year mean monthly temperature ranged from -14.4^{o}C to 29.7^{o}C (North Dakota State Climate Office 2016).

In Perkins County, we focused deer capture in a 1,492 km^2 area in the central portion of the county. Grasslands, cropland, and forested areas in Perkins County comprised 86, 11, and 0.01% of the land cover, respectively (Cropland Data Layer, U. S. Department of Agriculture 2015). White-tailed deer density was estimated at 1.2 ± 0.04 deer/km^2 during 2015 (K. Robling, South Dakota Department of Game, Fish and Parks, personal communication). Thirty-year mean annual precipitation in Perkins County was 44.9 cm and mean thirty-year monthly temperature ranged from -12.1^{o}C to 30.3^{o}C (North Dakota State Climate Office 2016).

Oil and natural gas development is prevalent in western North Dakota. For example, 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 2016). High production levels ranked North Dakota second and thirteenth in the nation for crude oil and natural gas production, respectively

(U. S. Department of Energy 2014). Currently, there are about 1,800 active oil wells in Dunn County producing about 64 million barrels of oil and 35 MCF of natural gas each year (Department of Mineral Resources 2016). Grant and Perkins counties capped and abandoned oil and natural gas wells by the 1980s due to low productivity (Department of Mineral Resources 2016, South Dakota Department of Environment and Natural Resources 2016).

Recreational hunting season dates for deer were similar across study areas and occurred from 4 September 2014 to 4 January 2015 and 4 September 2015 to 3 January 2016 in North Dakota. Recreational hunting for deer occurred from 27 September 2014 to 15 January 2015 and 26 September 2015 to 15 January 2016 in South Dakota.

MATERIALS AND METHODS

We captured adult female (>1.5-year-old) white-tailed deer via helicopter net guns (Native Range Capture Services, Elko, NV, USA, 2014) from 24 February to 2 March 2014. The helicopter crew hobbled, blindfolded, radio-collared, and collected blood at capture locations. We captured additional adult female deer in Grant County via helicopter net guns (Quicksilver Air Inc., Peyton, CO, USA, 2015) on 14 February 2015. Crews transported captured individuals below the helicopter in canvas transport bags to a nearby processing site. In 2015, we administered each individual 1 ml Banamine and 3 ml BO-SE (Selenium and Vitamin E, D. M. Grove, North Dakota Game and Fish Department, personal communication) before release. We considered any mortality that occurred within 26 days post-capture as capture-related mortality (Beringer et al. 1996).

We collected 20 ml of blood from each deer via jugular venipuncture. We allowed blood vials to warm to room temperature and clot before centrifugation. We then separated serum from cells via pipette and placed serum in cryovial tubes. We sent serum samples to Bio Tracking, Inc. (Moscow, ID, USA) to measure progesterone levels to determine pregnancy status. We sent serum samples to the North Dakota State University (NDSU) Veterinary Diagnostic Laboratory for analysis (NDSU, Fargo, ND, USA). Serum samples were analyzed for alkaline phosphatase (IU/L), aspartate aminotransferase (IU/L), albumin (ALB, g/dL), blood urea nitrogen (BUN, mg/dL), calcium (Ca, mg/dL), chloride (Cl, mEq/L), creatinine kinase (CK, md/dL), gamma-glutamyl transpeptidase (GGT, IU/L), globulin (GLOB, g/dL), glucose (GLU, mg/dL), lactate dehydrogenase (LDH, IU/L), magnesium (Mg, mg/dL), phosphorus (P, mg/dL), potassium (K, mEq/L), sodium (Na, mEq/L), and total protein (TP, g/dL).

The Minnesota Veterinary Diagnostic Laboratory (University of Minnesota, St. Paul, MN, USA) determined disease status from serum samples. Serum was tested for the following pathogens: *Anaplasma marginale*, *Borrelia*, *Brucella abortus*, bovine parainfluenza – 3 virus (PI3), bovine viral diarrhea virus type 1 and 2 (BVDV 1 and BVDV 2), bluetongue virus (BTV), epizootic hemorrhagic disease (EHD), infectious bovine rhinotracheitis (IBR), *Leptospira interrogans* spp., and *Neospora* spp. We sent additional serum samples to the National Veterinary Services Laboratory (U.S. Department of Agriculture, Ames, IA, USA) to test serum for the following pathogens: malignant catarrhal fever (MCF), West Nile Virus (WNV), and Eastern and Western equine encephalitis (EEE and WEE; respectively). The Diagnostic Center for Population and Animal Health (Michigan State University, Lansing, MI, USA) also tested lymph nodes collected from deceased deer for chronic wasting disease (CWD).

We used card agglutination to determine positive *A. marginale* titers at 1:320 and used indirect immunofluorescence assay (IFA) to determine positive *Borrelia* titers at 1:320. We used hemagglutination inhibition (HI) to determine positive PI3 titers at 1:10. We used serum neutralization (SN) to determine positive BVDV 1 and 2 and IBR titers at 1:8. We used microscopic agglutination test (MAT) to determine positive *L. interrogans* (*grippotyphosa*, *icterohaemorrhagiae*, *canicola*, *bratislava*, *pomona*, and *hardjo*) titers at 1:100. We used virus neutralization (VN) and peroxide linked assay (PLA) to determine MCF positive titers at 1:20. We used immunoglobin M (IgM) and immunoglobulin G (IgG) to detect West Nile Virus titers at 1:10.

We used enzyme-linked immunosorbent assay (ELISA) to detect EEE and WEE titers at 1:10. We used ELISA to detect positive *Neospora* spp. titers when sample to positive ratios (S:P) were greater than 0.50. We also used ELISA to test lymph nodes from mortalities for CWD. We used polymerase chain reaction (PCR) to detect BTV and EHD DNA presence. All capture and handling methods described in this study were approved by the Institutional Animal Care and Use Committee (13-091A) at South Dakota State University and followed guidelines for care and use of mammals established by the American Society of Mammalogists (Sikes et al. 2016).

Means and standard errors of nutritional indices were determined using descriptive statistics. Significant differences of nutritional indices among study areas were detected at $p < 0.05$ using an analysis of variance (ANOVA) in Program R. We analyzed tests from individuals captured in Grant County during 2015 separately because a number of nutritional indices differed between 2014 and 2015. We used a post-hoc Tukey's Test in Program R to compare results among study areas. We compared observed nutritional indices with published reference ranges (Tumbleson et al. 1968, Seal et al. 1981, Waid and Warren 1984). We did not have a reference range for aspartate aminotransferase. We did not test for alkaline phosphatase or LDH during 2015. We counted antibody prevalence and compared pathogen tests among study areas. Sample sizes for each nutritional indices and pathogen test varied depending on availability of serum from individual deer.

RESULTS

We captured and collected blood from 150 adult female deer via helicopter net guns in Dunn, Grant, and Perkins counties during 2014. Due to high mortality during 2014, we captured and drew blood from 15 additional female white-tailed deer via helicopter net guns in Grant County during 2015. We were able to obtain results from serum tests on 11 of 15 females captured in 2015 due to an insufficient amount of serum collected. We observed 7 total capture related mortalities (3 in 2014 and 4 in 2015) across all study areas, and the overall pregnancy rate was 96%.

We observed differences among study areas for nutritional indicators during 2014 (Table 4-1). We analyzed samples collected from Grant County during 2015 separately because differences were observed between years in Grant County for a number of parameters (Table 4-2). Dunn County CK values ($\bar{x} = 414.9$ SE = 38.10, n = 50) for deer were lower ($p < 0.001$) than for Grant and Perkins counties (Table 4-1). Deer in Grant County had GLOB ($\bar{x} = 2.95$, SE = 0.06, n = 50) and LDH ($\bar{x} = 1437.76$, SE = 76.73, n = 50) values that were higher ($p < 0.001$) than values in Dunn and Perkins counties. There were no differences ($p = 0.872$) in mean K values for deer among study areas, but we only tested one individual in Grant County during 2014 (Table 4-2). Perkins County GLU ($\bar{x} = 139.64$, SE = 5.77, n = 50) values for deer were lower ($p = 0.008$) than in Dunn and Grant counties. Perkins County deer had Mg ($\bar{x} = 3.04$, SE = 0.06, n = 50) and TP ($\bar{x} = 7.12$, SE = 0.15, n = 50) values that were higher ($p = 0.006$, $p = 0.034$, respectively) than in Dunn County but not different from Grant County. Sodium values for deer differed among all study areas ($p < 0.001$). Alkaline phosphatase, aspartate aminotransferase, ALB, BUN, Ca, Cl, GGT, K, and P values for deer did not differ among study areas in 2014 (Table 4-2).

Several nutritional indices were above the reference ranges reported by Seal et al. (1981) and Tumbleson et al. (1968) during 2014. Observed means for Cl, CK, GGT, GLOB, LDH, K, and Mg were above reference ranges for deer for those parameters (Appendix Table A-1). Perkins County mean ALB ($\bar{x} = 4.34$, SE = 0.05, n = 50) for deer was above the reference range (Appendix Table A-1). Observed means for P in Dunn ($\bar{x} = 8.92$, SE = 0.23, n = 50) and Perkins counties ($\bar{x} = 8.63$, SE = 8.63, n = 50) also were above the reference range (Appendix Table A-1). We observed greater than 60% of individuals with Cl, CK, GGT, GLOB, K, LDH, and Mg values above reference ranges established by Seal et al. (1981). Less than 50% of individuals had ALB, Ca, Na, P, and TP values above reference ranges (Seal et al. 1981). We observed less than 10% of individuals with BUN, Ca, CK, Cl, GLU, Na, and P values below reference ranges (Seal et al. 1981).

We observed differences in nutritional indices in Grant County between 2014 and 2015 (Table 4-2); observed means for ALB, Cl, CK, GGT, GLOB, GLU, K, Mg, Na, P, and TP differed ($p < 0.01$) between 2014 and 2015 (Table 4-2). Means for ALB, Cl, GGT, Mg, Na, P, and TP were lower ($p < 0.004$) in 2015 than 2014 in Grant County. Means for CK, GLOB, GLU, and K were higher ($p < 0.01$) in 2015 than 2014 in Grant County (Table 4-2). Means for Cl ($\bar{x} = 98.81$, SE = 0.69, n = 11) and Na ($\bar{x} = 129.05$, SE = 3.54, n = 11) during 2015 in Grant County were below the reference ranges for those parameters (Appendix Table A-2). Observed means for CK, GLOB, and K during 2015 in Grant County were higher than the reference ranges for those parameters (Appendix Table A-2). Observed serum values were within reference ranges for ALB, BUN, GLU, and TP. We observed 100% of individuals with CK, GLOB, and K values above reference ranges for those parameters. We observed less than 40% of individuals having Mg and GGT values above reference ranges (Seal et al. 1981). We observed more than 60% of individuals with Cl and Na values below reference ranges (Seal et al. 1981). Less than 40% of individuals had Ca and Mg values below reference ranges (Seal et al. 1981).

We observed differences in pathogen exposure among study areas (Table 4-3) and years in Grant County (Table 4-4). We detected antibodies for all infectious agents except *Brucella*, *Leptospira interrogans* serovars *canicola*, *hardio*, *icterohemorrhagica*, and Eastern and Western equine encephalitis. We did not detect antibodies for *Leptospira* spp. during 2015 in Grant County. No individuals tested positive for CWD during this study.

We observed differences in antibody prevalence among study areas during 2014 and 2015. Antibodies for WNV (79%), EHD (40%), and MCF (24%) were most prevalent in Dunn County (Table 4-3). Dunn County had fewer individuals with PI3 (8%), *A. marginale* (7%), *Neospora* spp (5%), and *Borrelia* (2%) antibodies (Table 4-3).

Antibodies for WNV (89%), PI3 (45%), and IBR (22%), were most prevalent in Grant County (Table 4-3). Grant County had fewer individuals with BVDV 1 and 2 (10%), *Leptospira* spp. (9%), MCF (8%), *A. marginale* (7%), *Neospora* spp. (7%), and *Borrelia* (6%) antibodies (Table 4-3). One individual in Grant County during 2014 had antibodies for both *L. pomona* and *L. bratislava*, and no individuals during 2015 had exposure to *Leptospira interrogans* serovars. Antibodies for WNV (86%), EHD (81%), MCF (62%), and PI3 (37%) were most prevalent in Perkins County (Table 4-3). Perkins County had fewer individuals with BTV (4%) and *Neospora* spp. (2%) antibodies (Table 4-3). While *Borrelia* antibodies were not prevalent in Perkins County, there were more individuals with *Borrelia* antibodies in Perkins County (20%) compared to Dunn (2%) and Grant (6%) counties. We observed high antibody prevalence for WNV (60%), IBR (33%), PI3 (27%), and MCF (20%) in Grant County during 2015 (Table 4-4). Grant County during 2015 had fewer individuals with *A. marginale*, *Borrelia*, and EHD (7%) antibodies during 2015 (Table 4-4). We did not detect *Brucella*, BVDV 1 and 2, *Leptospira* spp., EEE, or WEE antibodies in Grant County during 2015.

Observed titer levels were generally low for most pathogens. We observed nine individuals with titer levels of 1:16 and two individuals with levels of 1:32 for IBR. Most individuals had low titers to BVDV 1 and 2, but a few individuals had higher titer levels. We observed two individuals with titers of 1:32 and one individual with titers of 1:128 for BVDV 1. One individual had titers of 1:64 for BVDV 2. Individuals had antibodies for *L. i. bratislava*, *L. i. grippotyphosa*, and *L. i. pomona* and had titer levels of 1:100, 1:200, and 1:400. One individual had titer levels of 1:1600 for *L. i. pomona*. Ten individuals had titer levels of 1:80, six individuals had titer levels of 1:160, and one individual had titer levels of 1:320 for PI3. Most individuals had low titer levels for *Borrelia*, MCF, *Neospora* spp., and WNV.

DISCUSSION

Nutritional Indices

We observed a number of differences in nutritional indices among study areas and also between years for Grant County. Our results do not support our prediction that oil and natural gas development negatively impacts deer health. We did not observe consistent differences in nutritional indices in Dunn County compared to other study areas indicating that oil and natural gas development did not impact white-tailed deer health at the time of our investigation. Reasons for observed differences in nutritional indices are speculative, though they could be a result of variation in forage quality among study areas (Myers et al. 2015).

Sodium demands increase during growth and reproduction in female ungulates (Hellgren and Pitts 1997, Barboza et al. 2009). Female Na requirements are double those of males during gestation and lactation (Hewitt 2011). White-tailed deer females seek out mineral licks in spring and summer to supplement deficiencies in dietary Na during gestation and lactation (Kennedy et al. 1995). A high K intake can prevent absorption of Na exacerbating low Na levels (Weeks and Kirkpatrick 1976, Barboza et al. 2009). We observed differing Na values for all study areas with the lowest mean Na values in Grant County, and we observed high K values in all study areas. Potassium values did not vary significantly by study area possibly due to our small sample size during 2014.

Sodium values in all study areas during 2014 were higher than observed winter levels in the southern Black Hills during 2002-2003, but Na values observed in Grant County during 2015 were similar to winter values in the southern Black Hills (Zimmerman 2004). Winter K values in the southern Black Hills were higher than observed K values in all study areas during 2014, but were similar to K values observed in Grant County during 2015 (Zimmerman 2004). During our study, Grant County had lower fawn survival rates compared to Dunn and Perkins counties (Chapter 2)**,** and therefore, low mean Na in winter could be a limiting factor for reproduction in Grant County.

Calcium, K, and Mg are readily available in forage (Barboza et al. 2009, Hewitt 2011) and wild ungulates are rarely deficient in these elements (Barboza et al. 2009). Phosphorus is considered a limiting nutrient for herbivores because levels can be limited in forage (Hewitt 2011). Chloride is another important mineral but is not typically limited in the environment (Barboza et al. 2009). We observed over 80% of females with Cl and Mg values above reference ranges, but 90% of Ca and 50% of P values were within reference ranges (Seal et al. 1981). Winter Cl and P values in the southern Black Hills were similar to observed Cl and P values in all study areas during 2014, and Mg values for Grant and Perkins counties during 2014 were similar to winter Mg values in the southern Black Hills (Zimmerman 2004). Calcium values in all study areas during 2014 and 2015 were higher than winter Ca values in the southern Black Hills (Zimmerman 2004). Differences in nutritional indices in Grant County during 2014 and 2015 were most likely due to nutritional differences between years (Ditchkoff 2011). Our results could suggest that forage availability and quality differs among study areas and that forage availability differs between the reference area in Minnesota (Seal et al. 1981) and western North Dakota and northwestern South Dakota.

We observed nutritional indices above known reference ranges for CK, GLOB, GLU, and LDH (Seal et al. 1981) possibly due to our capture methods. Individuals that are immobilized for handling often have lower CK and stress levels (Montané et al. 2003). High GLOB levels also can be attributed to high levels of stress and inflammation in individuals (Rosef et al. 2004). High LDH and GLU levels can be attributed to chase time and capture from helicopter net-gunning (Klinger et al. 1986, Smith 2011). Jacques et al. (2009) found that capture related mortality increases with increased transport distance and pursuit time. We did not immobilize individuals during capture, which could explain our high CK values. Differences in capture methods, including longer pursuit and processing times during 2015 compared to 2014, could have contributed to higher CK, GLOB, GLU, and LDH levels in Grant County individuals during 2015.

High GGT levels may indicate liver injury resulting in reduced weight and performance in cattle (Moreira et al. 2012) and high TP levels may indicate inflammation or infection. Mean GGT values were not different among areas, but 45% of individuals displayed values outside of the reference range (Seal et al. 1981). Winter GGT and TP values in the southern Black Hills were lower than observed GGT and TP values in all study areas during 2014 and 2015. Dunn County deer had the highest mean GGT values followed by deer in Grant and Perkins counties, though the impacts of high GGT levels on deer are unknown. Although TP differed between Dunn and Perkins Counties, neither differed from Grant County. Less than 10% of females displayed TP values above the reference range (Seal et al. 1981) indicating levels of inflammation or infection were low or absent.

Pathogen Exposure

We were unable to detect effects of oil and natural gas development on white-tailed deer pathogen exposure. Our results, however, suggest that deer in the western Dakotas are exposed to a variety of livestock viruses regardless of energy development. We hypothesize that lower deer and livestock densities in Dunn County compared to Grant and Perkins counties decreased deer pathogen exposure in our energy development area. Our results provide baseline information for deer populations in the western Dakotas and document the potential for disease transmission between deer and livestock in the region.

We found high WNV antibody prevalence across study areas and years. White-tailed deer tested positive for WNV in New Jersey (Farajollahi et al. 2004) and Georgia (Miller et al. 2005), but only one deer mortality has been documented due to WNV (Miller et al. 2005). Five elk in Sioux County, North Dakota also tested positive for WNV during 2015 (W. Jensen, North Dakota Game and Fish Department, personal communication), but nine deer tested negative for WNV in the southern Black Hills during 2002-2003 (Zimmerman 2004). While avian species are severely affected, Miller et al. (2005) suggested that WNV is not a threat to deer populations because symptoms and mortality are unlikely, though knowledge of WNV effects on ungulate species are not well understood. The low neonate survival reported in Grant County (Chapter 2) may have been influenced by WNV infections; however, we did not collect blood from neonate mortalities to verify that conclusion. We hypothesize that WNV infections can cause neonate mortality if exposed to the disease and if exposure represents an additive stressor to other forms of mortality. More research is needed to assess impacts of WNV infections on deer health and survival.

Exposure to BTV and EHD varied among study areas with Grant County having the lowest EHD exposure rate (10%) and Perkins County having the highest EHD exposure rate (81%). Perkins County was the only study area with exposure to BTV, but displayed low prevalence (2%). Deer exposed to EHD and BTV are acutely affected (die within 24 to 48 hr) or chronically affected (recover after exposure; Thomas 1981). Historic EHD exposure rates in North Dakota approximate 7% (Sohn and Anderson 1991), which is similar to what we observed in Grant County. North Dakota observed high mortality from EHD during 2008, 2011, and 2013; epizootics caused high mortality in Grant County with few reports in Dunn County, indicating differences in intensity of exposure across the landscape (D. Grove, North Dakota Game and Fish Department, personal communication). Individuals exposed to the virus may have succumbed to the disease and were not present on the landscape during our sampling. This might explain lower exposure rate in Grant compared to Dunn and Perkins counties where individuals may have survived EHD outbreaks and thus, had a higher proportion of antibody prevalence.

We observed exposure to *Borrelia* in all study areas with a relatively high exposure rate in Perkins County compared to Dunn and Grant counties. The high exposure rate in Perkins County was similar to levels found in Minnesota (29%; Wolf et al. 2008). Wolf et al. (2008) attributed differences in *B. burgdorferi* antibody prevalence between study areas to one area providing more suitable habitat for *Ixodes scapularis*, but surveys in North and South Dakota have shown that *I. scapularis* was only present in eastern portions of the states (Russart et al. 2014, Maestas et al. 2016). Another *Borrelia* species other than *B. burgdorferi* may have been present or another bacteria caused a cross reaction during testing (D. Grove, North Dakota Game and Fish Department, personal communication). Further investigation will clarify the cause of the *Borrelia* antibody presence in the western Dakotas.

Our results indicate deer are exposed to a number of livestock pathogens on the landscape that are potentially influenced by farm operation type (Wolf et al. 2007). Most farm operations in the western Dakotas have cattle grazing, which facilitates increased deer exposure to livestock and disease transmission compared to farm operations that keep cattle contained. Deer are exposed to *Leptospira interrogans* due to their contact with cattle while sharing rangeland and potentially contaminated water sources (Myers et al. 2015). Cattle and sheep transmit MCF to deer, though our understanding of transmission is poor (Richards 1981). Differences in BVDV prevalence have been attributed to farm operation type in Minnesota (Wolf et al. 2008). Little is known why IBR varies by location, but increased contact with cattle is thought to increase exposure in some areas because cattle are reservoirs for the disease (Richards 1981, Van Campen et al 2001). Most deer fully recover from an infection from *A. marginale* or *Neospora* spp, but infected individuals are reservoir hosts of anaplasmosis and intermediate hosts of neosporosis and provide a source of disease for cattle (Kuttler 1981, Dubey et al. 1999). Higher MCF antibody prevalence in Perkins County could be explained by its higher sheep density (2.0 sheep/km^2) compared Dunn (0.4 sheep/km^2) and Grant (0.5 sheep/km^2) counties. We hypothesize that deer in the western Dakotas are not in close proximity to infected cattle resulting in low antibody prevalence, but the combination of higher deer and cattle densities in Grant County and moderate deer and cattle densities in Perkins County when compared to Dunn County could explain an increase in white-tailed deer exposure to pathogens.

We did not detect antibodies for *Brucella*, EEE, WEE, or have any individuals test positive for CWD during 2014 and 2015. North and South Dakota are brucellosis free (USDA 2016) and the absence of *Brucella* antibodies was consistent with that status. Little is known about wildlife as hosts of EEE and WEE, but several mammalian species have had high antibody prevalence (Seymour and Yuill et al. 1981). Surveillance testing in North Dakota has detected CWD at low prevalence levels (<1%) since its discovery in 2009. Despite radio-collared deer inhabiting the area of known positive animals, no mortalities tested positive indicating CWD prevalence was low in North Dakota.

Our results provide a reference range for white-tailed deer that may be used to compare to other deer populations across North America and for future herd health evaluations in the Western Dakotas. Collecting blood samples from individual deer over time would provide better results needed to determine effects of energy development on herd health. Additional research is needed to identify potential differences in forage quality and availability among study areas that may be responsible for differences in nutritional indices documented during our study. More information is needed to better understand the transmission of many livestock pathogens between cattle and wildlife populations, and particularly to better understand the potential impacts of WNV on deer survival and reproduction.

LITERATURE CITED

Barboza, P. S., K. L. Parker, and I. D. Hume. 2009. Integrative Wildlife Nutrition. Springer, New York, USA.

Beckmann, J. P., K. M. Berger, J. K. Young, and J. Berger. 2008. Wildlife and energy development: pronghorn of the Upper Green River Basin – year 3 summary. Wildlife Conservation Society, Bronx, NY. <http://www.wcs.org/yellowstone> Accessed 14 June 2016.

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

Billinis, C. 2012. Widlife diseases that pose a risk to small ruminants and their farmers. Lectures of the 1st European Conference on Small Ruminant Health Management 110:67-70.

Bryce, S. J. M. Omernik, D. E. Pater, M. Ulmer, J. Schaar, J. Freeouf, R. Johnson, P. Kuck, and S. H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. (Map poster). U.S. Geological Survey, Jamestown, ND.

DelGiudice, G. D., L. D. Mech, U. S. Seal, and P. D. Karns. 1987. Effects of winter fasting and refeeding on white-tailed deer blood profiles. Journal of Wildlife Management 51:865-873.

DelGiudice, G. D., L. D. Mech, K. E. Kunkel, E. M. Gese, and U. S. Seal. 1991. Seasonal patterns of weight, hematology, and serum characteristics of free-ranging female white-tailed deer in Minnesota. Canadian Journal of Zoology 70:974-983.

DeLiberto, T. J., J. A. Pfister, S. Demarais, G. Van Vreede. 1989. Seasonal changes in physiological parameters of white-tailed deer in Oklahoma. Journal of Wildlife Management 53:533-539.

Department of Mineral Resources [DMR] Oil and Gas Division. 2016. DMR Homepage. <https://www.dmr.nd.gov/> Accessed 14 June 2016.

Ditchkoff, S. S. 2011. Anatomy and physiology. Pages 43-73 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Dubay, S. A., T. H. Noon, J. C. deVos, Jr., and R. A. Ockenfels. 2006. Serologic survey from pathogens potentially affecting pronghorn (*Antilocapra americana*) fawn recruitment in Arizona, USA. Journal of Wildlife Disease 42:844-848.

Dubay, S., C. Jacques, N. Golden, B. Kern, K. Mahoney, A. Norton. 2015. Environmental factors influencing white-tailed deer (*Odocoileus virginianus*) exposure to livestock pathogens in Wisconsin. PLoS ONE 10(6):e0128827.doi:10.1371/journal.pone.0128827.

Dubey, J. P., K. Hollis, S. Romand, P. Thulliez, O. C. H. Kwok, L. Hungerford, C. Anchor, and D. Etter. 1999. High prevalence of antibodies to *Neospora caninum* in white-tailed deer (*Odocoileous virginianus*). International Journal of Parasitology 29:1709-1711.

Edge, W. 1982. Distribution, Habitat Use, and Movements of Elk in Relation to Roads and Human Disturbances in Western Montana. University of Montana. Missoula, MT.

Farajollahi, A., R. Gates, W. Crans, and N. Komar. 2004. Serologic evidence of West Nile virus and St. Louis Encephalitis virus infections in white-tailed deer (*Odocoileus virginianus*) from New Jersey, 2001. Vector Borne and Zoonotic Diseases 4:379-383.

Gilbert, A. T., A. R. Fooks, D. L. Horton, T. Muller, R. Plowright, A. J. Peel, R. Bowen, J. L. N. Woods, J. Mills, A. A. Cunningham, and C. E. Rupprecht. 2013. Deciphering serology to understand the ecology of infectious diseases in wildlife. EcoHealth 10:298-313.

Gill, J. S., R. G. McLean, R. B. Shriner, and R. C. Johnson. 1994. Serologic surveillance for the lyme disease spirochete, *Borrelia burgdorferi*, in Minnesota by using white-tailed deer as sentinel animals. Journal of Clinical Microbiology 32:444-451.

Gill, R. B., T. D. I. Beck, C. J. Bishop, D. J. Freddy, N. T. Hobbs, R. H. Kahn, M. W. Miller, T. M. Pojar, and G. C. White. 2001. Declining mule deer populations in Colorado: reasons and responses. Special Report 77, Colorado Division of Wildlife, Fort Collins, USA, 30pp.

Hellgren, E. C. and W. J. Pitts. 1997. Sodium economy in white-tailed deer (*Odocoileus virginianus*). Physiological Zoology 70:547-555.

Hewitt, D. G. 2011. Nutrition. Pages 75-105 *in* D. G. Hewitt, editor. Biology and management of white-tailed deer. CRC Press, Boca Raton, Florida, USA.

Jacques, C. N., J. A. Jenks, C. S. DePerno, J. D. Sievers, T. W. Grovenburg, T. J. Brinkman, C. C. Swanson, and B. A. Stillings. 2009. Evaluating ungulate mortality associated with helicopter net-gun captures in the Northern Great Plains. Journal of Wildlife Management 8:1282-1291.

Kennedy, J. F., J. A. Jenks, R. L. Jones, and K. J. Jenkins. 1995. Characteristics of mineral licks used by white-tailed deer (*Odocoileus virginianus*). The American Midland Naturalist 2:324-331.

Klinger, S. R., R. J. Robel, B. A. Brown, and B. E. Brent. 1986. Blood characteristics of white-tailed deer from northeastern Kansas. Journal of Wildlife Disease 22:385-388.

Kuttler, K. L. 1981. Miscellaneous viral diseases. Diseases and parasites of white-tailed deer. Davidson, W. R., F. A. Hayes, V. F. Nettles, and F. E. Kellogg, editors. Tall Timbers Research Station Misc. Publication No. 7:126-137.

Maestas, L. P., S. L. Adams, and H. B. Britten. 2016. First evidence of an established population of *Ixodes scapularis* (Acari:Ixodidae) in South Dakota. Journal of Medical Entomology 53:965-966.

Miller, D. L., Z. A. Radi, C. Baldwin, and D. Ingram. 2005. Fatal West Nile virus infection in a white-tailed deer (*Odocoileus virginianus*). Journal of Wildlife Disease 41:246-249.

Montané, J., I. Marco, J. López-Olvera, D. Perpiñán, X. Manteca, and S. Lavín. 2003. Effects of acepromazine on capture stress in roe deer (*Capreolus capreolus*). Journal of Wildlife Diseases 39:375-386.

Moreira, C. N., S. N. Souza, A. C. Barini, E. G. Araujo, M. C. S. Fioravanti. 2012. Serum γ-glutamyltransferase activity as an indicator of chronic liver injury in cattle with no clinical signs. Brazilian Journal of Veterinary and Animal Science. 64:1403-1410.

Myers, W. L., W. J. Foreyt, P. A Talcott, J. F. Evermann, and W. Chang. 2015. Serologic, trace element, and fecal parasite survey of free-ranging, female mule deer (*Odocoileus hemionus*) in eastern Washington, USA. Journal of Wildlife Disease 51:125-136.

North Dakota State Climate Office. 2016. Monthly station normal of temperature, precipitation, and heating and cooling degree days 1981-2010. <https://www.ndsu.edu/ndsco/data/30yearaverage/#c343059> Accessed 12 July 2016.

Richards, S. H. 1981. Miscellaneous viral diseases. Diseases and parasites of white-tailed deer. Davidson, W. R., F. A. Hayes, V. F. Nettles, and F. E. Kellogg, editors. Tall Timbers Research Station Misc. Publication No. 7:108-125.

Rosef, O., H. L. Nystøyl, T. Solenes, and J. M. Arnemo. 2004. Haematological and serum biochemical reference values in free-ranging red deer (*Cervus elaphus atlanticus*). Rangifer 24:79-85.

Rost, G. and J. Bailey. 1979. Distribution of mule deer and elk in relation to roads. The Journal of Wildlife Management 43:634-641.

Roug, A., P. Swift, S. Torres, K. Jones, and C. K. Johnson. 2012. Serosurveillance for livestock pathogens in free-ranging mule deer (Odocoileus hemionus). PLoS ONE 7(11): e50600. Doi:10.1371/journal.pone.0050600.

Russart, N. M., M. W. Dougherty, and J. A. Vaughan. 2014. Survey of tick: (Acari:Ixodidae) and tick-borne pathogens in North Dakota. The Journal of Medical Entomology 51:1087-1090.

Sawyer, H., R. Nielson, D. Stickland, and L. McDonald. 2005. Mule Deer Study (Phase II): Long-term Monitoring Plan to Assess Potential Impacts of Energy Development on Mule Deer in the Pinedale Anticline Project Area. Western Ecosystems Technology, Inc., Cheyenne, WY.

Sawyer, H., R. Nielson, F. Lindzey, and L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. Journal of Wildlife Management 70:396-403.

Seal, U. S., L. J. Verme, and J. J. Ozoga. 1981. Physiologic values. Diseases and parasites of white-tailed deer. Davidson, W. R., F. A. Hayes, V. F. Nettles, and F. E. Kellogg, editors. Tall Timbers Research Station Misc. Publication No. 7:17-33.

Seymour, C. and T. M. Yuill. 1981. Arboviruses. Infectious diseases of wild mammals, 2nd edition. J. W. Davis, L. H. Karstad, and D. O. Trainer, editors. Iowa State University Press, Ames, Iowa, USA.

Sherrill, B. L., A. G. Snider, S. Kennedy-Stoskopf, and C. S. DePerno. 2012. Survey of zoonotic pathogens in white-tailed deer on Bald Head Island, North Carolina. Southeastern Naturalist 11:529-533.

Sikes, R. S., and the Animal Care and Use Committee of the American Society of Mammalogists. 2016. 2016 Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy Volume 97, Issue 3, pages 663—688.

Smith, M. L. 2011. Blood chemistry of free-ranging and captive white-tailed deer (Odocoileus virginianus) in Texas. Thesis, Texas A & M University, College Station, Texas.

Sohn, R. and R. Anderson. 1991. Study No. A-V: The maintenance and transmission of epizootic hemorrhagic disease of deer and bluetongue virus in North Dakota wildlife. North Dakota State Game and Fish Department, Bismarck, North Dakota, USA.

South Dakota Department of Environment and Natural Resources [DENR]. 2016. DENR homepage. http://denr.sd.gov>Accessed 14 June 2016.

Stankowich, T. 2008. Ungulate flight responses to human disturbance: a review and meta-analysis. Biological Conservation 141:2159-2173.

Stillings, B., B. Jensen, and J. Smith. 2012. Study No. C-I: Deer population studies. North Dakota Game and Fish Department. Bismarck, ND, USA.

Thomas, F. C. 1981. Hemorrhagic disease. Diseases and parasites of white-tailed deer. Davidson, W. R., F. A. Hayes, V. F. Nettles, and F. E. Kellogg, editors. Tall Timbers Research Station Misc. Publication No. 7:17-33.

Tumbleson, M. E., M. G. Wood, A. R. Dommert, D. A. Murphy, and L. J. Korschgen. 1968. Biochemic studies on serum from white-tailed deer in Missouri. American Journal of Veterinary Clinic Pathology 2:121.

U. S. Department of Agriculture (USDA). 2014. USDA, National Agricultural Statistics Service (NASS), 2012 Census of Agriculture. NASS Marketing and Information Services, Office, Washington, D. C., USA.

U. S. Department of Agriculture (USDA). 2015. USDA, National Agricultural Statistics Service (NASS), Cropland Data Layer. USDA, NASS Marketing and Information Services Office, Washington, D.C., USA.

U. S. Department of Energy. 2014. U. S. Energy Information Administration, Rankings: Total Energy Consumed per Capita, 2014. Energy Information Administration Office, Washington, D. C., USA.

U. S. Geological Survey (USGS). 2 May 2013. USGS releases new oil and gas assessment for Bakken and Three Forks Formations. <https://www2.usgs.gov/blogs/features/ usgs_top_story/usgs-releases-new-oil-and-gas-assessment-for-bakken-and-three-forks-formations/> Accessed 6 April 2016.

Van Campen, H., J Ridpath, E. Williams, J. Cavender, J. Edwards, S. Scott, and H. Sawyer. 2001. Isolation of bovine viral diarrhea virus from a free-ranging mule deer in Wyoming. Journal of Wildlife Disease 37:306-311.

Van Dyke, F., A. Fox, S. M. Harju, M. R. Dzialak, L. D. Hayden-Wing, and J. B. Winstead. 2012. Response of Elk to habitat modification near natural gas development. The Journal of Environmental Management 50:942-955.

Waid, D. D. and R. J. Warren. 1984. Seasonal variations in physiological indices of adult female white-tailed deer in Texas. Journal of Wildlife Disease 20:212-219.

Walker, B. L., D. E. Naugle, and K. E. Doherty. 2007. Greater sage-grouse population response to energy development and habitat loss. Journal of Wildlife Management 71:2644-2654.

Weeks, H. P., Jr. and C. M. Kirkpatrick. 1976. Adaptations of white-tailed deer to naturally occurring sodium deficiencies. Journal of Wildlife Management 40:610-625.

White, M. and R. S. Cook. 1974. Blood characteristics of free-ranging white-tailed deer in southern Texas. Journal of Wildlife Diseases 10:18-24.

Wolf, K. N., C. S. DePerno, J. A. Jenks, M. K. Stoskopf, S. Kennedy-Stoskopf, C. C. Swanson, T. J. Brinkman, R. G. Osborn, ad J. A. Tardiff. 2008. Selenium status and antibodies to selected pathogens in white-tailed deer (*Odocoileus virginianus*) in southern Minnesota. Journal of Wildlife Disease 44:181-187.

Zimmerman, T. J. 2004. Effects of fire on the nutritional ecology of selected ungulates in the southern Black Hills, South Dakota. Thesis, South Dakota State University, Brookings, South Dakota.

Table 4-1. Nutritional indices for radio-collared female white-tailed deer in Dunn and Grant Counties, North Dakota and Perkins County, South Dakota during 2014.

	Dunn		Grant		Perkins		
Blood Chemistry Parameter	**Mean ± SE**	**n**	**Mean ± SE**	**n**	**Mean ± SE**	**n**	**P-values**
Albumin (g/dL)	4.11± 0.05	50	4.14 ± 0.05	49	4.34 ± 0.18	50	0.302
Alkaline Phosphatase (IU/L)	54.32 ± 3.04	50	56.50 ± 2.04	50	63.18 ± 3.66	49	0.183
Aspartate Aminotransferase (IU/L)	154.96 ± 7.23	50	175.30 ± 7.65	50	198.58 ± 25.30	50	0.153
Blood Urea Nitrogen (mg/dL)	23.38 ± 1.01	50	20.62 ± 0.85	50	23.24 ± 0.97	50	0.070
Calcium (mg/dL)	10.39 ± 0.61	50	9.79 ± 0.07	50	9.74 ± 0.12	50	0.367
Chloride (mEq/L)	113.60 ± 0.52	50	112.92 ± 1.25	50	113.80 ± 0.38	48	0.654
Creatinine Kinase (md/dL)*	414.88 ± 38.10	50	614.92 ± 30.32	49	730.06 ± 46.70	48	<0.001
Gamma-Glutamyl Transpeptidase (IU/L)	118.84 ± 4.34	50	116.36 ± 4.25	50	111.92 ± 3.73	49	0.488
Globulin (g/dL)**	2.67 ± 0.04	50	2.95 ± 0.06	50	2.74 ± 0.04	46	<0.001
Glucose (mg/dL)***	157.08 ± 4.64	50	161.26 ± 4.89	50	139.64 ± 5.77	50	0.008
Lactate Dehydrogenase (IU/L)**	1152.42 ± 49.93	50	1437.76 ± 76.73	50	1160.08 ± 46.25	49	<0.001
Magnesium (mg/dL)****	2.81 ± 0.03	50	2.94 ± 0.06	50	3.04 ± 0.06	50	0.006
Phosphorus (mg/dL)	8.92 ± 0.23	50	8.15 ± 0.19	50	8.63 ± 0.30	50	0.082
Potassium (mEq/L)	12.70 ± 0.38	22	13.50 ± 0.00	1	25.19 ± 3.18	14	0.872
Sodium (mEq/L)*****	152.50 ± 0.81	50	140.34 ± 2.03	50	146.38 ± 1.20	48	<0.001
Total Protein (g/dL)****	6.78 ± 0.06	50	7.09 ± 0.07	50	7.12 ± 0.15	50	0.034

* Dunn County differs from Grant and Perkins counties.
** Grant County differs from Dunn and Perkins counties.
*** Perkins County differs from Dunn and Grant counties.
**** Perkins County differs from Dunn County.
***** All counties differ

Table 4-2. Nutritional indices for radio-collared female white-tailed deer in Grant County North Dakota during 2015.

Blood Chemistry Parameter	**Mean ± SE**	**n**	**p-value[a]**
Albumin (g/dL)	3.29 ± 0.05	11	0.002
Aspartate Aminotransferase (IU/L)	177.17 ± 35.60	11	0.98
Blood Urea Nitrogen (mg/dL)	22.09 ± 1.81	11	0.878
Calcium (mg/dL)	9.11 ± 0.09	11	0.267
Chloride (mEq/L)	98.81 ± 0.69	11	<0.001
Creatinine Kinase (md/dL)	2007.55 ± 1144.82	11	<0.001
Gamma-Glutamyl Transpeptidase (IU/L)	71.84 ± 12.08	10	<0.001
Globulin (g/dL)	3.08 ± 0.17	11	0.01
Glucose (mg/dL)	183.45 ± 16.13	11	0.01
Magnesium (mg/dL)	2.44 ± 0.09	11	<0.001
Phosphorus (mg/dL)	5.54 ± 0.35	11	<0.001
Potassium (mEq/L)	28.51 ± 3.40	11	<0.001
Sodium (mEq/L)	129.05 ± 3.54	11	<0.001
Total Protein (g/dL)	6.36 ± 0.13	11	0.004

[a] p-value comparing individuals from 2014 and 2015 in Grant County.

Table 4-3. Pathogen exposure rates (# positive/# tested) of female white-tailed deer in Dunn and Grant Counties, North Dakota and Perkins County, South Dakota during 2014.

		No. positive/total tested (%)		
Agent	**Total Positive/ Sample**	**Dunn**	**Grant**	**Perkins**
Anaplasma marginale	5/118 (4%)	3/44 (7%)	2/29 (7%)	0/45 (0%)
Borrelia	14/146 (10%)	1/47 (2%)	3/49 (6%)	10/50 (20%)
Brucella abortus	0/131 (0%)	0/36 (0%)	0/49 (0%)	0/46 (0%)
Bovine Parainfluenza – 3 Virus	33/114 (29%)	3/39 (8%)	13/29 (45%)	17/46 (37%)
Bovine Viral Diarrhea Virus Type 1	3/150 (2%)	0/50 (0%)	3/50 (6%)	0/50 (0%)
Bovine Viral Diarrhea Virus Type 2	2/150 (1%)	0/50 (0%)	2/50 (4%)	0/50 (0%)
Bluetongue Virus	2/150 (1%)	0/50 (0%)	0/50 (0%)	2/50 (4%)
Epizootic Hemorrhagic Disease	62/128 (48%)	20/50 (40%)	3/30 (10%)	39/48 (81%)
Infectious Bovine Rhinotracheitis	28/150 (19%)	6/50 (12%)	11/50 (22%)	11/50 (22%)
L. grippotyphosa	1/150 (1%)	0/50 (0%)	0/50 (0%)	1/50 (2%)
L. bratislava	12/150 (8%)	3/50 (6%)	4/50 (8%)	5/50 (10%)
L. pomona	7/150 (5%)	5/50 (10%)	1/50 (1%)	1/50 (1%)
Malignant Catarrhal Fever	33/103 (32%)	7/29 (24%)	3/37 (8%)	23/37 (62%)
Neospora spp.	5/117 (4%)	2/43 (5%)	2/29 (7%)	1/45 (2%)
West Nile Virus	87/102 (85%)	23/29 (79%)	32/36 (89%)	32/37 (86%)
Eastern and Western Equine Encephalitis	0/118 (0%)	0/29 (0%)	0/52 (0%)	0/37 (0%)
Chronic Wasting Disease	0/9 (0%)	0/1 (0%)	0/7 (0%)	0/1 (0%)

Table 4-4. Pathogen exposure rates (# positive/# tested) of female white-tailed deer in Grant County, North Dakota during 2015.

Agent	**No. positive/total tested (%)**
Anaplasma marginale	1/15 (7%)
Borrelia	1/15 (7%)
Brucella abortus	0/15 (0%)
Bovine Parainfluenza – 3 Virus	4/15 (27%)
Bovine Viral Diarrhea Virus Type 1	2/15 (13%)
Bovine Viral Diarrhea Virus Type 2	0/15 (0%)
Bluetongue Virus	0/15 (0%)
Epizootic Hemorrhagic Disease	1/15 (7%)
Infectious Bovine Rhinotracheitis	5/15 (33%)
Leptospira spp.[a]	0/15 (0%)
Malignant Catarrhal Fever	3/15 (20%)
Neospora spp.	2/15 (13%)
West Nile Virus	9/15 (60%)
Eastern and Western Equine Encephalitis	0/15 (0%
Chronic Wasting Disease	0/6 (0%)

[a] *Leptospira interrogans* spp. serovars tested include *bratislava*, *canicola*, *grippotyphosa*, *hardjo*, *icterohemorrhagica*, and *pomona*.

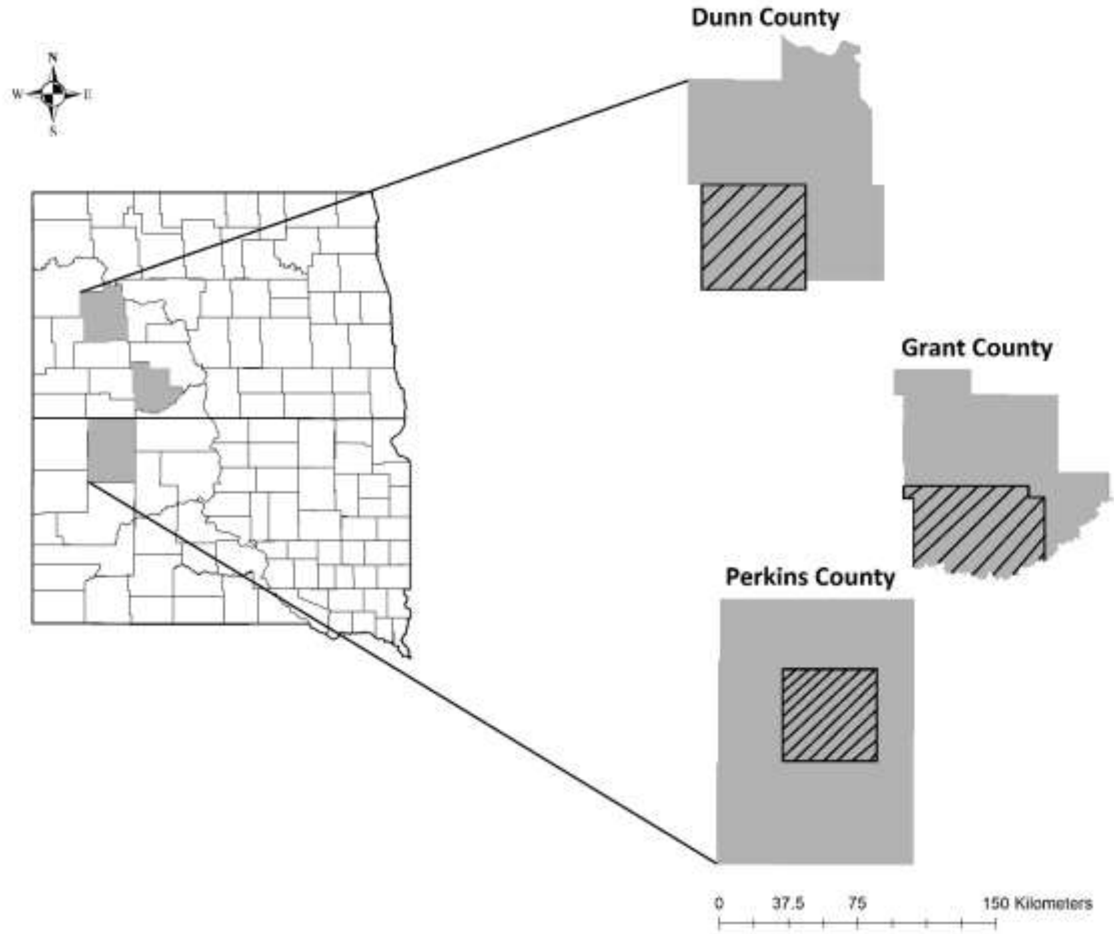

Figure 4-1. Study areas where adult female white-tailed deer (*Odocoileus virginianus*) were captured and radio-collared in Dunn and Grant counties, North Dakota and Perkins County, South Dakota, USA. Dashed lines indicate deer capture areas within each study area.

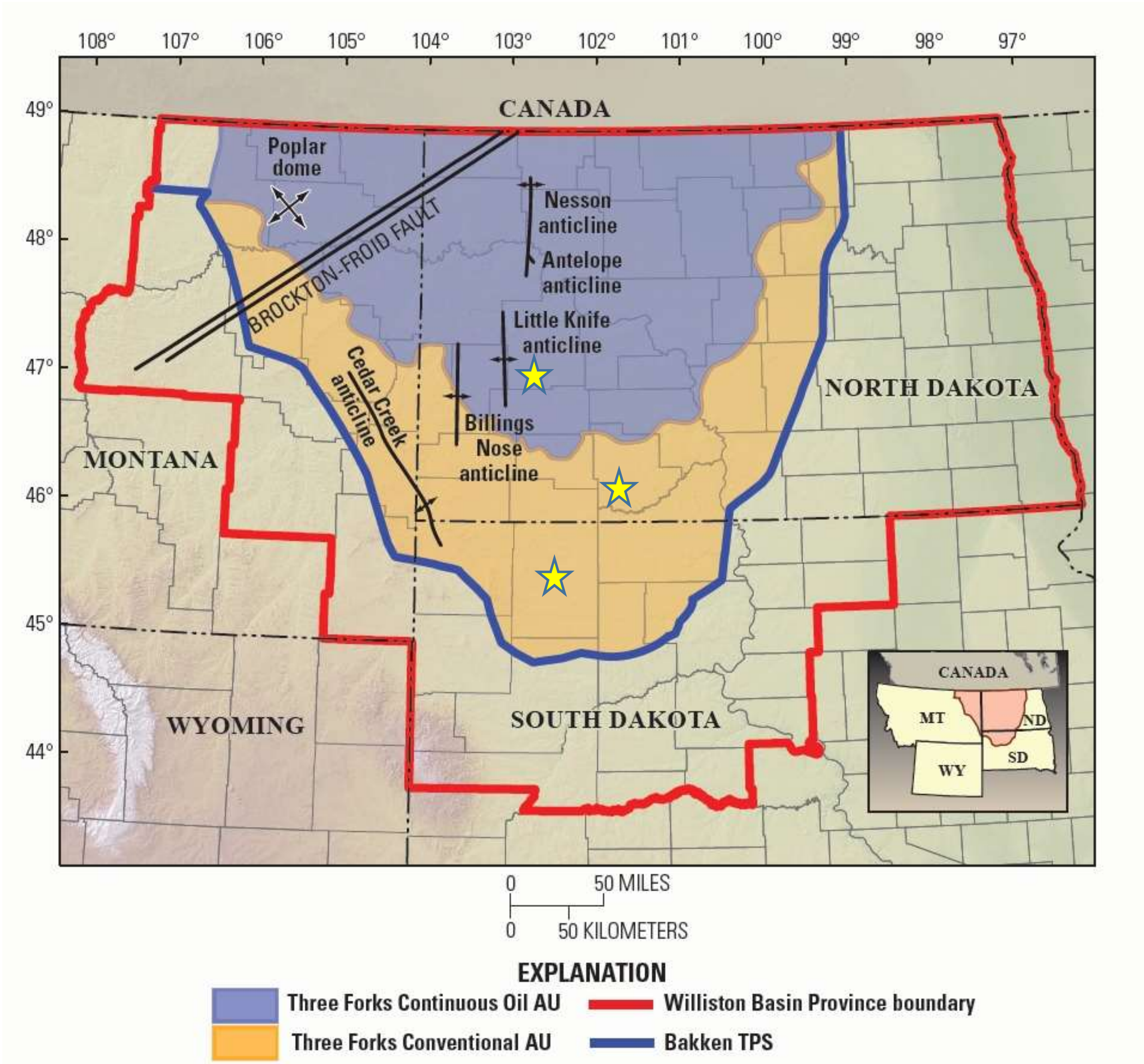

Figure 4-2. Bakken-Three Forks Formations in the Williston Basin in the Northern Great Plains (U. S. Geological Survey 2013). Yellow stars denote study areas.

APPENDIX A

Table A-1. Nutritional indices for radio-collared female white-tailed deer in Dunn and Grant Counties, North Dakota and Perkins County, South Dakota during 2014.

Blood Chemistry Parameter	Dunn		Grant		Perkins		Reference Range[a]
	Mean ± SE	**Range**	**Mean ± SE**	**Range**	**Mean + SE**	**Range**	
Albumin (g/dL)	4.11 ± 0.05	3.50-4.90	4.14 ± 0.05	3.10-4.80	4.34 ± 0.18	2.50-12	2.50-4.20
Alkaline Phosphatase (IU/L)	54.32 ± 3.04	12-147	56.50 ± 2.04	17-132	63.18 ± 3.66	29-145	10-200[b]
Aspartate Aminotransferase (IU/L)	154.96 ± 7.23	75-344	175.30 ± 7.65	72-317	198.58 ± 25.30	93-1384	n/a
Blood Urea Nitrogen (mg/dL)	23.38 ± 1.01	13-43	20.62 ± 0.85	4-32	23.24 ± 0.97	13-57	15-45
Calcium (mg/dL)	10.39 ± 0.61	8.70-40.10	9.79 ± 0.07	8.50-11.10	9.74 ± 0.12	6.60-12	8.80-10.80
Chloride (mEq/L)	113.60 ± 0.52	108-133	112.92 ± 1.25	53-117	113.80 ± 0.38	109-123	100-110
Creatinine Kinase (md/dL)*	414.88 ± 38.10	103-1486	614.92 ± 30.32	196-1041	730.06 ± 46.70	13-2007	20-400
Gamma-Glutamyl Transpeptidase (IU/L)	118.84 ± 4.34	50-231	116.36 ± 4.25	50-247	111.92 ± 3.73	80-227	40-100
Globulin (g/dL)**	2.67 ± 0.04	2.30-3.60	2.95 ± 0.06	2.40-4.30	2.74 ± 0.04	2.2-3.40	0.40-1.00
Glucose (mg/dL)***	157.08 ± 4.64	82-243	161.26 ± 4.89	90-243	139.64 ± 5.77	23-212	60-320
Lactate Dehydrogenase (IU/L)**	1152.42 ± 49.93	112-2377	1437.76 ± 76.73	866-3486	1160.08 ± 46.25	590-2800	100-300

Magnesium (mg/dL)****	2.81 ± 0.03	2.4-3.52	2.94 ± 0.06	2.36-4.34	3.04 ± 0.06	2.30-4.40	2.2-2.6[c]
Phosphorus (mg/dL)	8.92 ± 0.23	5.80-12	8.15 ± 0.19	5.00-10.50	8.63 ± 0.30	2.94-13.80	4.50-8.50
Potassium (mEq/L)	12.70 ± 0.38	8.90-14.80	13.50 ± 0.00	13.50	25.19 ± 3.18	12.90-50.81	3.40-5.00
Sodium (mEq/L)*****	152.50 ± 0.81	133-161	140.34 ± 2.03	61-157	146.38 ± 1.20	127-161	132-156
Total Protein (g/dL)****	6.78 ± 0.06	6-7.90	7.09 ± 0.07	5.80-8.50	7.12 ± 0.15	6-13.50	5.00-7.80

[a] Data ranges were reported by Seal et al. (1981) unless otherwise indicated.
[b] Data ranges reported by Waid and Warren (1984).
[c] Data ranges reported by Tumbleson et al. (1968).
* Dunn County differs from Grant and Perkins counties.
** Grant County differs from Dunn and Perkins counties.
*** Perkins County differs from Dunn and Grant counties.
**** Perkins County differs from Dunn County.
***** All counties differ

Table A-2. Nutritional indices for radio-collared female white-tailed deer in Grant County, North Dakota during 2015.

Blood Chemistry Parameter	**Mean ± SE**	**Range**	**Reference Range[a]**
Albumin (g/dL)	3.29 ± 0.05	3.14-3.76	2.50-4.20
Aspartate Aminotransferase (IU/L)	177.17 ± 35.60	95.80-508.40	n/a
Blood Urea Nitrogen (mg/dL)	22.09 ± 1.81	15.80-31.90	15-45
Calcium (mg/dL)	9.11 ± 0.09	8.57-9.65	8.80-10.80
Chloride (mEq/L)	98.81 ± 0.69	96-103.90	100-110
Creatinine Kinase (md/dL)	2007.55 ± 1144.82	419-13,378	20-400
Gamma-Glutamyl Transpeptidase (IU/L)	71.84 ± 12.08	48.10-176.50	40-100
Globulin (g/dL)	3.08 ± 0.17	1.60-4	0.40-1.00
Glucose (mg/dL)	183.45 ± 16.13	96-276	60-320
Magnesium (mg/dL)	2.44 ± 0.09	1.98-3.04	2.2-2.6[b]
Phosphorus (mg/dL)	5.54 ± 0.35	3.96-7.21	4.50-8.50
Potassium (mEq/L)	28.51 ± 3.40	14.33-50.81	3.40-5.00
Sodium (mEq/L)	129.05 ± 3.54	109.70-143.80	132-156
Total Protein (g/dL)	6.36 ± 0.13	5.40-7.10	5.00-7.80

[a] Data ranges were reported by Seal et al. (1981) unless otherwise indicated.
[b] Data ranges reported by Waid and Warren (1984).

CHAPTER 5: MANAGEMENT IMPLICATIONS

The North Dakota Game and Fish Department and the South Dakota Department of Game, Fish and Parks require information on oil and natural gas development impacts on white-tailed deer (*Odocoileus virginianus*) to appropriately manage deer in the western Dakotas. Our study provides the first data on white-tailed deer responses to oil and natural gas development in the western Dakotas and suggests that mule deer (*Odocoileus hemionus*) may not serve as an accurate surrogate for energy development impacts on white-tailed deer.

We did not detect negative impacts on fawn and female survival rates from oil and gas development in the western Dakotas at this time but negative impacts may have occurred prior to the start of the study, or may occur in the future as oil and natural gas development expands. Wildlife managers should continue to provide adequate habitat in oil and natural gas development areas to provide individuals with cover and resources while avoiding developing areas, especially during winter. Long-term studies in the region are needed to assess lag-effects in response to oil and natural gas development.

Nutritional indices and pathogen testing did not indicate that oil and natural gas development impacted white-tailed deer health, but did indicate that deer health varied by study area. White-tailed deer are exposed to a number of livestock pathogens on the landscape. Disease management may be difficult, especially in areas where livestock are allowed to roam large tracts of land and have higher probability of coming in contact with wildlife. Nutritional indices likely vary due to differences in forage quality and availability among study areas. Our results provide baseline values for white-tailed deer in western North Dakota and northwestern South Dakota that can be used to track herd health over time and compare to other white-tailed deer populations in North America. Future habitat analysis could assess differences in forage quality and availability among the study areas.

Grant County fawn and adult female survival was low compared to Dunn and Perkins counties. The deer population in Grant County is higher than in other counties in our study, and competition for resources may be limiting recruitment. Increasing the amount of quality winter deer range will help to decrease intraspecific competition. If density-dependent factors are impacting Grant County white-tailed deer, increased deer harvest in Grant County would decrease competition for resources and likely improve fawn survival. Female survival in Grant County was similar to survival reported elsewhere for white-tailed deer and thus, it is reasonable to believe that female survival in that area was at normal levels. Habitat improvements and lower deer densities in Grant County may increase survival to similar levels observed in Dunn and Perkins counties. Anecdotal evidence suggest West Nile Virus (WNV) may play a role in fawn survival, and warrants further investigation.

Considering what capture methods were used in a study is important when assessing fawn survival. Vaginal implant transmitters (VITs) are a common and efficient tool aiding in fawn capture within 24 hours of birth. This technique allows researchers to capture accurate survival rates at early stages of life. If researchers choose not to use VITs, our study indicates that there is potential to overestimate fawn survival by over 20%. When using a combination of VITs and opportunistic captures of fawns to estimate survival rates, large groups (≥ 10) of personnel should be used to search for and radio-collar fawns early in the season. Determining peak parturition dates and timing search efforts before peak parturition is critical. This technique allows researchers to capture fawns when they are most vulnerable to mortality and to accurately estimate survival.

The North Dakota Game and Fish Department surveys deer during late winter in western North Dakota to estimate deer populations and set harvest goals. We observed 90% of Post-hunt mortalities occurring in March and April after survey periods. We recommend the state move survey dates as late as possible while snow is present to account for late-winter mortalities, radio-collar and monitor a representative sample of white-tailed deer to access mortality, or develop additional late season population indices to assess changes in population numbers. Population models should include an estimated late-winter mortality factor to remove individuals from the population estimate if later survey dates are not possible.

Our project has evaluated species-specific information on impacts of oil and natural gas development on white-tailed deer health and survival available to the North Dakota Game and Fish Department and the South Dakota Department of Game, Fish and Parks. White-tailed deer are an adaptable species that are able to overcome habitat changes and at low densities are able to acclimate to oil and natural gas development. However, continuous monitoring is needed in the region to assess changes in survival and health as deer density and oil and natural gas well densities are dynamic.

APPENDIX B

Table B-1. Survival summary for female white-tailed deer radio-collared in Dunn County, North Dakota during 1 and 2 March 2014.

Doe ID	Frequency	VIT Frequency	Mortality Date	Fate	Last Active		
					Date	Latitude	Longitude
250	155.152	153.998			14-Dec-15	47.152360	-102.636890
251	155.164	154.009			14-Dec-15	46.974160	-102.630660
252	155.194	154.019			14-Dec-15	47.256100	-102.399770
253	155.216	154.028			14-Dec-15	47.199410	-103.303510
254	155.225	154.039			14-Dec-15	47.12339	-102.4162
255	155.235	154.049			14-Dec-15	46.979	-102.90768
256	155.245	154.059			14-Dec-15	47.31833	-102.45077
257	155.255	154.069	7-Dec-15	Starvation due to broken leg	1-Dec-15	47.16087	-102.95549
258	155.264	154.079			14-Dec-15	47.36857	-102.55888
259	155.272	154.088			14-Dec-15	47.03587	-102.67214
260	155.285	154.099			14-Dec-15	46.97092	-102.62099
261	155.295	154.109			14-Dec-15	47.11235	-102.91184
262	155.305	154.12			14-Dec-15	47.25197	-102.34286
263	155.316	154.129			14-Dec-15	46.99086	-102.90276
264	155.325	154.139			14-Dec-15	47.09577	-102.70607
265	155.333	154.148			14-Dec-15	46.9906	-102.66212
266	155.343	154.159			14-Dec-15	46.96815	-103.14899
267	155.354	154.167			14-Dec-15	46.98919	-102.90239
268	155.362	154.177			14-Dec-15	47.04573	-102.72972
269	155.373	154.189			14-Dec-15	47.2546	-103.05721
270	155.414	154.199			14-Dec-15	47.20604	-102.53577
271	155.424	154.209			14-Dec-15	47.04739	-103.01493

272	155.435	154.219	19-Oct-14	Unknown	15-Oct-14	47.072870	-102.778570
273	155.444	154.229			14-Dec-15	47.03874	-102.71961
274	155.454	154.238	5-Nov-15	Unknown	22-Oct-15	47.14444	-102.43903
275	155.464	154.249			14-Dec-15	47.01307	-102.87789
276	155.473	154.258			14-Dec-15	47.03661	-102.72307
277	155.484	154.269			14-Dec-15	47.10657	-102.92066
278	155.494	154.279			14-Dec-15	47.14182	-102.43063
279	155.503	154.289			14-Dec-15	46.98309	-102.90175
280	155.514	NA			14-Dec-15	47.04435	-102.85329
281	155.525	NA			14-Dec-15	47.10546	-102.89738
282	155.534	NA			14-Dec-15	47.20487	-102.70683
283	155.545	NA			14-Dec-15	47.27709	-102.72612
284	155.555	NA			14-Dec-15	46.96991	-102.82892
285	155.564	NA	30-Apr-14	Predation	18-Apr-14	47.265225	-102.839999
286	155.584	NA			14-Dec-15	47.25868	-102.44473
287	155.593	NA			14-Dec-15	46.99696	-102.64685
288	155.614	NA			14-Dec-15	47.07266	-102.68584
289	155.643	NA			14-Dec-15	47.09305	-102.9383
290	155.673	NA			14-Dec-15	47.28303	-102.47321
291	155.703	NA			14-Dec-15	46.96933	-102.62092
292	155.734	NA			14-Dec-15	47.01722	-102.89228
293	155.764	NA			14-Dec-15	47.11559	-102.94779
294	155.794	NA			14-Dec-15	47.33587	-102.48863
295	155.824	NA			14-Dec-15	46.98207	-102.59769
296	155.854	NA			14-Dec-15	47.08332	-103.01323
297	155.915	NA			14-Dec-15	47.11017	-102.95141
298	155.945	NA			14-Dec-15	47.23988	-102.7262
299	155.974	NA			14-Dec-15	47.14694	-102.45684

Table B-2. Survival summary for female white-tailed deer radio-collared in Grant County, North Dakota during 27 and 28 February 2014.

Doe ID	Frequency	VIT Frequency	Mortality Date	Fate	Last Active		
					Date	Latitude	Longitude
200	150.013	150.513			14-Dec-15	46.013080	-101.556980
201	150.023	150.522	4-Feb-15	Predation	30-Jan-15	46.253650	-101.981030
202	150.033	150.531	22-Apr-14	Predation	14-Apr-14	46.322480	-101.806720
203	150.042	150.543			14-Dec-15	46.181421	-101.823267
204	150.053	150.552			14-Dec-15	46.017878	-101.647003
205	150.064	150.563	8-Nov-14	Hunter Harvest	6-Nov-15	46.102380	-101.973250
206	150.072	150.572	18-Mar-14	Capture Myopathy	11-Mar-14	N/A	N/A
207	150.081	150.581			14-Dec-15	46.062865	-101.934835
208	150.095	150.591	11-Mar-15	Predation	5-Mar-15	46.227800	-101.774500
209	150.104	150.602			14-Dec-15	46.214760	-101.727730
210	150.113	150.611	12-Mar-15	Unknown	2-Mar-15	46.285730	-101.733799
211	150.123	150.621			14-Dec-15	46.267180	-101.904370
212	150.134	150.633	8-Mar-14	Capture Myopathy	N/A	N/A	N/A
213	150.144	150.642			14-Dec-15	46.360882	-101.908184
214	150.154	150.652	22-Nov-14	Hunter Harvest	19-Nov-14	46.154130	-101.818980
215	150.164	150.663	9-Oct-14	Grain Overload-wheat	3-Oct-14	46.212830	-102.097360
216	150.174	150.671			14-Dec-15	46.012070	-101.557050
217	150.184	150.682			14-Dec-15	46.133233	-102.111267
218	150.194	150.692			14-Dec-15	46.124490	-101.869710
219	150.203	150.702			14-Dec-15	46.029900	-101.556490
220	150.214	150.712	20-Nov-14	Hunter Harvest	19-Nov-14	46.308550	-101.718700
221	150.224	150.722			14-Dec-15	46.315215	-101.795221
222	150.236	150.733	24-Oct-15	Hit By Vehicle	22-Oct-15	46.450190	-101.891430
223	150.243	150.742			14-Dec-15	46.023224	-102.126697

224	150.253	150.752	18-Apr-14	Predation	14-Apr-14	N/A	N/A
225	150.263	150.762			14-Dec-15	46.036050	-102.188730
226	150.275	150.772	13-Nov-16	Hunter Harvest	14-Dec-15	46.302999	-101.863649
227	150.284	150.782			14-Dec-15	46.046556	-102.051224
228	150.293	150.792	30-May-14	Disease-Parturition Stress	26-May-14	46.252052	-101.776330
229	150.305	150.801	22-Apr-14	Coyote Predation	14-Apr-14	46.086770	-101.964370
230	150.314	NA			14-Dec-15	46.199810	-101.803620
231	150.323	NA	6-Mar-15	Unknown	27-Feb-15	46.009300	-102.174250
232	150.335	NA			14-Dec-15	46.238540	-101.589160
233	150.344	NA			14-Dec-15	46.059177	-101.928215
234	150.353	NA	10-Dec-14	Coyote Predation	5-Dec-14	46.196540	-101.718180
235	150.364	NA			14-Dec-15	46.111240	-102.010055
236	150.373	NA			14-Dec-15	46.288312	-101.611420
237	150.384	NA			14-Dec-15	46.183940	-102.082750
238	150.393	NA	21-Nov-15	Hunter Harvest	20-Nov-15	46.331173	-101.814829
239	150.403	NA			14-Dec-15	46.177760	-101.720630
240	150.413	NA			14-Dec-15	46.015610	-101.556450
241	150.422	NA			14-Dec-15	46.057535	-101.931899
242	150.434	NA	2-Dec-15	Predation	30-Nov-15	46.180760	-101.836910
243	150.443	NA	26-Nov-14	Predation	25-Nov-14	46.196090	-101.724200
244	150.453	NA	19-Jun-14	Unknown	9-Jun-14	46.019900	-101.610060
245	150.462	NA			14-Dec-15	46.364759	-102.019400
246	150.473	NA	13-Sep-14	EHD	11-Sep-14	46.408670	-101.788100
247	150.483	NA			14-Dec-15	46.227400	-101.829800
248	150.493	NA			14-Dec-15	46.352540	-101.517520
249	150.504	NA			14-Dec-15	46.075700	-101.936040

Table B-3. Survival summary for female white-tailed deer radio-collared in Perkins County, South Dakota during 25 and 26 February 2014.

Doe ID	Frequency	VIT Frequency	Mortality Date	Fate	Last Active		
					Date	Latitude	Longitude
300	150.003	151.001	15-Nov-14	Grain Overload	14-Nov-14	45.437150	-102.394430
301	150.013	151.012			7-May-15	45.76366	-102.06606
302	150.024	151.022			7-Nov-15	45.5185	-102.59515
303	150.033	151.032			7-May-15	45.749	-102.41306
304	150.043	151.043			16-May-15	45.35137	-102.168
305	150.052	151.051			9-Nov-15	45.31546	-102.25734
306	150.063	151.063			20-Aug-14	45.586420	-102.744160
307	150.072	151.074			7-Nov-15	45.41605	-102.50179
308	150.082	151.094			9-Nov-15	45.31546	-102.25734
309	150.093	151.103			29-Oct-15	45.4146	-102.48846
310	150.103	151.113			7-Nov-15	45.46684	-102.57025
311	150.114	151.123			9-Nov-15	45.3145	-102.26968
312	150.123	151.135			22-Oct-15	45.31824	-102.27045
313	150.134	151.144			9-Nov-15	45.48653	-102.24078
314	150.143	151.153			7-Nov-15	45.51657	-102.59171
315	150.154	151.163			7-Nov-15	45.4951	-102.38568
316	150.163	151.172	19-May-15	Predation	12-May-15	45.40684	-102.48264
317	150.174	151.193			12-Jan-15	45.541260	-102.443150
318	150.183	151.203			7-Nov-15	45.51657	-102.59171
319	150.194	151.214			7-Nov-15	45.42566	-102.442
320	150.203	151.223			7-Nov-15	45.40152	-102.4318
321	150.213	151.233			9-Nov-15	45.47099	-102.26561
322	150.223	151.244	4-Mar-14	Capture Myopathy	31-Mar-14	45.504056	-102.581250
323	150.235	N/A			9-Nov-15	45.49432	-102.23838

324	150.243	151.262			5-Nov-15	45.35052	-102.30264
325	150.253	151.272			9-Nov-15	45.5358	-102.28524
326	150.264	151.293			7-Nov-15	45.50676	-102.57892
327	150.274	151.301			9-Nov-15	45.5358	-102.28524
328	150.283	151.313			5-Nov-15	45.34521	-102.30264
329	150.293	151.322			11-Apr-15	45.41386	-102.48145
330	150.305	N/A			7-Nov-15	45.51802	-102.58485
331	150.315	151.193			9-Nov-15	45.32626	-102.23962
332	150.323	N/A			9-Nov-15	45.23184	-102.28908
333	150.334	N/A			9-Nov-15	45.54446	-102.29279
334	150.343	N/A	18-Nov-15	Hunter Harvest	7-Nov-15	45.51506	-102.59491
335	150.353	N/A			29-Oct-15	45.42275	-102.4277
336	150.364	N/A			22-May-15	45.52831	-102.26113
337	150.373	N/A	22-Jul-15	Hit By Vehicle	17-Jul-15	45.52962	-102.28493
338	150.384	N/A			7-Nov-15	45.51994	-102.59103
339	150.394	N/A	27-Nov-15	Unknown	5-Nov-15	45.3227	-102.26507
340	150.403	N/A	20-Nov-15	Hunter Harvest	1-Aug-15	45.431730	-102.057690
341	150.413	N/A			9-Nov-15	45.54273	-102.19535
342	150.423	N/A			7-Nov-15	45.49099	-102.606
343	150.433	N/A			7-Nov-15	45.46203	-102.51732
344	150.443	N/A			7-Nov-15	45.39212	-102.4209
345	150.453	N/A			5-Nov-15	45.38817	-102.26706
346	150.462	N/A			7-Nov-15	45.50846	-102.58804
347	150.473	N/A			7-Nov-15	45.42799	-102.43046
348	150.483	N/A	7-Dec-14	Censored Unknown	11-Apr-14	45.540361	-102.409194
349	150.493	N/A			9-Nov-15	45.54706	-102.28538

Table B-4. Survival summary for female white-tailed deer radio-collared in Grant County, North Dakota during 14 February 2015.

Doe ID	Frequency	VIT Frequency	Mortality Date	Fate	Last Active		
					Date	Latitude	Longitude
350	150.033	150.512			14-Dec-15	46.289020	-101.766720
351	150.072	150.522	24-Feb-15	Capture Myopathy	19-Feb-15	N/A	N/A
352	150.134	150.542	1-Oct-16	Hit By Vehicle	14-Dec-15	46.370740	-101.767300
353	150.154	150.562	17-Mar-15	Predation	16-Mar-15	46.333490	-101.893940
354	150.164	150.572			14-Dec-15	46.240150	-101.784750
355	150.293	NA	24-Feb-15	Capture Myopathy	19-Feb-15	N/A	N/A
356	150.305	150.602			14-Feb-15	46.325080	-101.880200
357	150.353	150.621	24-Feb-15	Capture Myopathy	19-Feb-15	N/A	N/A
358	150.443	150.633			14-Dec-15	46.190110	-101.769710
359	150.473	150.641	21-Apr-15	Unknown	17-Apr-15	46.336748	-101.938659
360	153.439	150.682			14-Dec-15	46.263361	-101.780118
361	153.629	NA			14-Dec-15	46.152396	-101.765880
362	153.749	150.702			14-Dec-15	46.344660	-101.910220
363	153.788	150.711	6-Mar-15	Capture Myopathy	24-Feb-15	46.324880	-101.795060
364	153.809	150.723			14-Dec-15	46.182423	-101.766122

Table B-5. Survival summary of neonate white-tailed deer radio-collared in Dunn County, North Dakota during 2014 and 2015.

Fawn ID	Frequency	Capture Date	VIT Capture	Sex	Age at Capture (Days)	Mortality Date	Fate	Last Active
D1	154.159	27-May-14	Y	M	0	21 Oct 14	Dropped Collar	18-Oct-14
D2	154.269	27-May-14	Y	M	0	15 Oct 14	Dropped Collar	14-Oct-14
D3	154.130	30-May-14	Y	M	1			15-May-15
D4	154.289	30-May-14	Y	M	1	17 Nov 14	Dropped Collar	12-Nov-14
D5	154.009	31-May-14	Y	M	1			24-Feb-15
D6	154.189	2-Jun-14	Y	F	0	2 Oct 14	Dropped Collar	26-Sep-14
D7	154.239	2-Jun-14	Y	F	0	4 Jun 14	Abandoned	3-Jun-14
D8	154.150	5-Jun-14	Y	F	2			29-Apr-15
D9	154.040	7-Jun-14	Y	M	1	25 Nov 14	Dropped Collar	21-Nov-14
D10	154.099	8-Jun-14	Y	F	1	30 Jun 14	Disease-Bilateral Uveitus	29-Jun-14
D11	154.220	9-Jun-14	Y	M	1	13 Oct 14	Dropped Collar	7-Oct-14
D12	154.199	9-Jun-14	Y	M	1	22 Jan 15	Dropped Collar	14-Jan-15
D13	154.059	9-Jun-14	Y	F	2	1 Nov 14	Dropped Collar	28-Oct-14
D14	154.000	9-Jun-14	Y	M	2	22 Jan 15	Dropped Collar	16-Jan-15
D15	154.019	10-Jun-14	N	M	7.	11 Mar 15	Dropped Collar	5-Mar-15
D16	154.279	11-Jun-14	N	F	8			19-Jun-15
D17	154.119	11-Jun-14	N	M	8	4 Feb 15	Dropped Collar	27-Jan-15
D18	154.259	11-Jun-14	Y	M	8	18 Nov 14	Unknown	15-Nov-14
D19	154.229	11-Jun-14	Y	F	8			2-Sep-15
D20	154.089	11-Jun-14	Y	F	8	30 Jun 14	Predation	19-Jun-14
D21	154.049	11-Jun-14	Y	F	0	17 Mar 15	Dropped Collar	31-May-15
D22	154.179	11-Jun-14	Y	M	0			31-May-15
D23	154.109	12-Jun-14	Y	F	1	21 Apr 15	Dropped Collar	9-Apr-15
D24	154.139	13-Jun-14	N	F	8	7 Oct 14	Dropped Collar	1-Oct-15
D25	154.209	13-Jun-14	Y	F	2	20 Jun 14	Predation	19-Jun-14

D26	154.070	15-Jun-14	Y	M	0	19 Jun 14	Predation	18-Jun-14
D27	154.029	15-Jun-14	Y	F	0	19 Jun 14	Predation	18-Jun-14
D28	154.249	19-Jun-14	Y	M	0			22-May-15
D29	154.079	19-Jun-14	Y	M	0			5-Mar-15
D30	154.158	1-Jun-15	N	F	4			20-Jun-15
D31	154.258	7-Jun-15	N	F	3	15 Jun 15	Predation	14-Jun-15
D32	154.428	7-Jun-15	N	F	3	22 Sept 15	Predation	16-Sep-15
D33	154.368	8-Jun-15	N	F	3	13 Oct 15	Dropped Collar	13-Oct-15
D34	154.098	8-Jun-15	N	F	0			14-Dec-15
D35	154.329	8-Jun-15	N	M	0			14-Dec-15
D36	154.308	9-Jun-15	N	M	4			14-Dec-15
D37	154.409	9-Jun-15	N	F	4			14-Dec-15
D38	154.269	9-Jun-15	N	M	0			14-Dec-15
D39	154.138	10-Jun-15	N	M	3	7 Nov 15	Hunter Harvest	7-Nov-15
D40	154.208	10-Jun-15	N	M	0			14-Dec-15
D41	154.059	10-Jun-15	N	M	0			14-Dec-15
D42	154.029	12-Jun-15	N	M	4			14-Dec-15
D43	154.289	13-Jun-15	N	M	4			14-Dec-15
D44	154.318	14-Jun-15	N	F	4			14-Dec-15
D45	154.340	15-Jun-15	N	M	0			14-Dec-15
D46	154.400	18-Jun-15	N	M	4	20 Jun 15	Predation	19-Jun-15
D47	154.220	20-Jun-15	N	F	4			14-Dec-15
D48	154.040	21-Jun-15	N	F	5			14-Dec-15

Table B-6. Survival summary of neonate white-tailed deer radio-collared in Grant County, North Dakota during 2014 and 2015.

Fawn ID	Frequency	Capture Date	VIT Capture	Sex	Age at Capture (Days)	Mortality Date	Fate	Last Active
G1	150.632	26-May-14	Y	F	0	28-May-14	Unknown	27-May-14
G2	150.541	31-May-14	Y	M	1	25-Jun-14	Predation	24-Jun-14
G3	150.703	4-Jun-14	Y	F	7	13-Jun-14	Predation	12-Jun-14
G4	150.562	5-Jun-14	Y	M	0	14-Jun-14	Unknown-Predation Suspected	7-Jun-14
G5	150.641	5-Jun-14	Y	F	0	25-Jun-14	Unknown-Predation Suspected	24-Jun-14
G6	150.671	5-Jun-14	Y	M	0		Unknown-Last Heard	1-Apr-15
G7	150.730	8-Jun-14	Y	M	1	2-Jul-14	Unknown-Predation Suspected	1-Jul-14
G8	150.712	10-Jun-14	Y	M	0	24-Jun-14	Predation	23-Jun-14
G9	150.531	12-Jun-14	Y	F	0		Censored-Last Heard	27-May-15
G10	150.660	12-Jun-14	Y	M	8		Censored-Last Heard	27-May-15
G11	150.570	13-Jun-14	Y	F	0	7-Aug-14	Unknown-Predation Suspected	4-Aug-14
G12	150.722	14-Jun-14	Y	F	1	24-Jun-14	Unknown-Predation Suspected	23-Jun-14
G13	150.761	14-Jun-14	N	M	10	14 Jul 14	Dropped Collar	13-Jul-14
G14	150.611	15-Jun-14	Y	M	0		Censored-Last Heard	10-Jul-14
G15	150.603	15-Jun-14	N	M	7	21-Jun-14	Disease-Birth Defect/Incomplete Urethra	20-Jun-14
G16	150.771	16-Jun-14	N	M	8	23 Jun 15	Dropped Collar	1-Apr-15
G17	150.792	16-Jun-14	N	M	7	10-Nov-14	Hunter Harvest	4-Nov-14
G18	150.552	17-Jun-14	N	F	10	7 Jan 15	Dropped Collar	16-Dec-14
G19	150.632	20-Jun-14	Y	M	0	9-Jul-14	Unknown	29-Jun-14
G20	150.582	20-Jun-14	Y	M	0	13 Juy 15	Dropped Collar	6-Jul-15
G21	150.792	1-Jun-15	Y	M	0	17-Jun-15	Predation	16-Jun-15
G22	150.543	1-Jun-15	Y	F	0			14-Dec-15
G23	150.703	3-Jun-15	N	M	7	11-Jun-15	Unknown	10-Jun-15
G24	150.762	3-Jun-15	N	M	0		Censored-Last Heard	8-Jul-15

G25	150.570	4-Jun-15	N	F	9	13 Aug 15	Dropped Collar	10-Aug-15
G26	150.730	5-Jun-15	N	M	8	18 Aug 15	Dropped Collar	14-Aug-15
G27	151.674	9-Jun-15	N	M	6	13-Jun-15	Unknown-Predation Suspected	12-Jun-15
G28	150.621	9-Jun-15	N	M	0	30-Jun-15	Predation	29-Jun-15
G29	151.584	9-Jun-15	N	F	9			14-Dec-15
G30	151.774	10-Jun-15	N	F	13			14-Dec-15
G31	150.552	10-Jun-15	N	M	8		Censored-Last Heard	17-Sep-15
G32	150.592	14-Jun-15	N	M	11	4-Aug-15	Predation	31-Jul-15
G33	150.512	14-Jun-15	N	F	7	21 Oct 15	Dropped Collar	14-Oct-15
G34	150.802	14-Jun-15	N	M	8		Censored-Last Heard	1-Oct-15
G35	150.711	17-Jun-15	Y	M	0			14-Dec-15
G36	150.632	17-Jun-15	Y	M	0			14-Dec-15
G37	150.682	18-Jun-15	N	M	6			14-Dec-15
G38	150.651	19-Jun-15	N	M	6	21-Nov-15	Hunter Harvest	20-Nov-15
G39	151.614	21-Jun-15	N	M	6	2-Nov-15	Censored Unknown-No Permission	22-Oct-15
G40	150.522	23-Jun-15	N	F	6			10-Dec-15

Table B-7. Survival summary of neonate white-tailed deer radio-collared in Perkins County, South Dakota during 2014 and 2015.

Fawn ID	Frequency	Capture Date	VIT Capture	Sex	Age at Capture (Days)	Mortality Date	Fate	Last Active
P1	151.194	23-May-14	N	F	8	11-Jul-14	Unknown	8-Jul-14
P2	151.233	25-May-14	Y	F	8	8-Aug-15	Censored Unknown-No Permission	27-May-15
P3	151.302	25-May-14	Y	M	0	19-Sep-15	Censored Unknown-No Permission	8-Aug-15
P4	151.000	27-May-14	N	M	5	2-Feb-15	Disease-Grain Overload	30-Jan-15
P5	151.122	30-May-14	N	F	10	11 Jul 15	Dropped Collar	2-Jul-15
P6	151.262	30-May-14	N	M	5	30 Jun 14	Dropped Collar	29-Jun-14
P7	151.323	31-May-14	Y	F	7	14 Aug 14	Dropped Collar	11-Aug-14
P8	151.353	1-Jun-14	N	F	0			6-Apr-15
P9	151.344	1-Jun-14	Y	M	0			6-Apr-15
P10	151.334	3-Jun-14	Y	F	0	28-Nov-15	Censored Unknown-No Permission	25-Mar-15
P11	151.252	3-Jun-14	N	M	6	1-Nov-15	Poached	30-Sep-15
P12	151.161	5-Jun-14	Y	F	1			1-Nov-15
P13	151.292	5-Jun-14	Y	F	1			1-Nov-15
P14	151.362	5-Jun-14	N	M	8	8-Jul-14	Disease-EHD/BVDV	7-Jul-14
P15	151.044	6-Jun-14	N	M	9	1 Oct 15	Dropped Collar	6-Apr-15
P16	151.092	6-Jun-14	N	M	7	11-Jun-14	Unknown-Predation Suspected	10-Jun-14
P17	151.134	6-Jun-14	N	M	7	5 Jul 14	Dropped Collar	4-Jul-14
P18	151.142	7-Jun-14	N	F	6	3-Jul-14	Unknown-Predation Suspected	2-Jul-14
P19	151.244	9-Jun-14	N	M	9			1-Nov-15
P20	151.012	9-Jun-14	N	F	3	30-Jun-14	Predation	29-Jun-14

P21	151.052	10-Jun-14	Y	M	8			28-Mar-15
P22	151.203	10-Jun-14	Y	M	8			28-Mar-15
P23	151.073	10-Jun-14	N	M	6	20-Nov-14	Hunter Harvest	18-Nov-14
P24	151.034	10-Jun-14	N	M	5	18-Dec-14	Unknown-Predation Suspected	15-Dec-14
P25	151.674	10-Jun-14	Y	F	8	2 Feb 15	Dropped Collar	30-Jan-15
P26	150.222	11-Jun-14	N	M	5	5-Aug-14	EHD/BVDV	1-Aug-14
P27	151.213	12-Jun-14	N	M	11	30-Sep-15	Unknown	2-Apr-15
P28	151.023	12-Jun-14	N	M	9	5-Aug-14	Unknown-Predation Suspected	1-Aug-14
P29	151.173	13-Jun-14	Y	M	0			1-Nov-15
P30	151.273	13-Jun-14	Y	M	0	10-Jul-14	Unknown-Predation Suspected	9-Jul-14
P31	150.663	14-Jun-14	Y	M	0	9-Jul-14	Predation	8-Jul-14
P32	151.223	14-Jun-14	N	F	8	30-Sep-15	Censored Unknown-No Permission	15-Sep-15
P33	151.755	16-Jun-14	Y	M	5	21-Jun-14	Predation	20-Jun-14
P34	150.592	16-Jun-14	N	F	6	25 Jun 14	Dropped Collar	24-Jun-14
P35	151.773	17-Jun-14	N	M	4	23 Jun 15	Dropped Collar	20-Jun-15
P36	150.612	27-May-15	N	F	8			28-Nov-15
P37	150.512	28-May-15	N	F	8			28-Nov-15
P38	150.742	28-May-15	N	M	8	16-Nov-15	Censored Unknown-No Permission	11-Nov-15
P39	150.702	31-May-15	N	M	13	5-Jun-15	Unknown	4-Jun-15
P40	150.782	1-Jun-15	N	F	6	14 Jun 15	Dropped Collar	13-Jun-15
P41	150.892	1-Jun-15	N	M	8			28-Nov-15
P42	150.552	1-Jun-15	N	M	8			28-Nov-15
P43	150.652	1-Jun-15	N	M	8			28-Nov-15
P44	150.882	1-Jun-15	N	M	9			28-Nov-15
P45	151.432	1-Jun-15	N	F	9			28-Nov-15
P46	150.812	1-Jun-15	N	M	8.1			28-Nov-15

P47	150.633	1-Jun-15	N	M	8			28-Nov-15
P48	150.543	2-Jun-15	N	M	0			28-Nov-15
P49	151.263	2-Jun-15	N	M	0	14 Nov 15	Dropped Collar	11-Nov-15
P50	150.572	2-Jun-15	N	F	7	17-Jul-15	Unknown-Predation Suspected	13-Jul-15
P51	150.902	2-Jun-15	N	F	11			28-Nov-15
P52	150.773	2-Jun-15	N	M	6			28-Nov-15
P53	150.682	2-Jun-15	N	F	8	27 Sep 15	Dropped Collar	22-Sep-15
P54	150.721	2-Jun-15	N	M	3	3-Jun-15	Capture Myopathy	2-Jun-15
P55	150.582	2-Jun-15	N	M	1			28-Nov-15
P56	150.843	2-Jun-15	N	F	9			28-Nov-15
P57	150.523	2-Jun-15	N	F	7	7-Jun-15	Capture Myopathy	6-Jun-15
P58	150.603	2-Jun-15	N	F	0			28-Nov-15
P59	150.821	2-Jun-15	N	M	8	13 Aug 15	Dropped Collar	7-Aug-15
P60	151.634	2-Jun-15	N	M	8			28-Nov-15
P61	150.852	3-Jun-15	N	M	8			28-Nov-15
P62	150.622	3-Jun-15	N		8			28-Nov-15
P63	150.642	6-Jun-15	N	M	8	11-Jun-15	Abandoned	10-Jun-15
P64	150.711	8-Jun-15	N	M	5	27 Oct 15	Dropped Collar	23-Oct-15
P65	150.803	8-Jun-15	N	M	5	5 Nov 15	Dropped Collar	1-Nov-15
P66	151.642	8-Jun-15	N	F	5			28-Nov-15
P67	150.504	10-Jun-15	N	M	5			28-Nov-15
P68	151.513	12-Jun-15	N	M	5			28-Nov-15
P69	150.872	12-Jun-15	N	F	5	20 Sep 15	Dropped Collar	15-Sep-15