GAME REPORT

Movement patterns, survival, and sightability of mule deer in central and western South Dakota

Completion Report

By

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ABSTRACT

Movement patterns, survival, and sightability of mule deer in central and western South Dakota

Few techniques have proved successful at providing reasonable estimates of mule deer (*Odocoileus hemionus*) abundance. Primary objectives of this study were to determine and evaluate factors affecting sightability of mule deer during winter and spring and develop spring and winter sightability models for aerial surveying of mule deer in western and central South Dakota. From January 2010 - March 2012, 128 adult female and 10 adult male radio-collared mule deer (*n*=78, Meade and Pennington Counties; *n*=60, Fort Pierre National Grasslands (FPNG)) were monitored and utilized to develop sightability models for estimating deer densities. Data collected during both spring and winter flights included group size, activity, habitat, topography, and visual obstruction. Twenty-three spring sightability flights were conducted in April within the Meade-Pennington (*n*=9) and FPNG (*n*=14) study areas when potential color differences between sun-bleached deer and spring green-up of vegetation were present. Within the Meade-Pennington study area deer were sighted in the spring at a rate of 9.3% (10/107). Logistic regression analysis indicated that visibility was influenced by canopy cover; however, the best model indicated through information-theoretic methods was not significant. Within the FPNG study area deer were sighted in the spring at a rate of 65.7% (167/253). Logistic regression analysis indicated that visibility was significantly influenced by group size, activity and topography. Twenty-four winter sightability flights were conducted between January – March in the Meade-Pennington (*n*=11) and FPNG (*n*=13) study areas when 100% snow cover was present. An additional eight winter flights were flown in the FPNG study area when no snow cover was

present. Within the Meade-Pennington study area deer were sighted in the winter at a rate of 31.2% (34/109). Logistic regression analysis indicated that visibility was influenced by canopy cover and group size; however, the best model indicated through information-theoretic methods was not significant. Within the FPNG study area, deer were sighted in the winter at a rate of 84.6% (252/298) when 100% snow cover was present. Logistic regression analysis indicated that visibility was significantly influenced by group size and topography. Winter sightability rates in the FPNG study area when no snow cover was present were 58.5% (55/94). Logistic regression analysis indicated that visibility was significantly influenced by group size, activity, topography and visual obstruction.

The models that were developed in the FPNG study area will assist managers in estimating population size of mule deer in open prairie landscapes in central and western South Dakota. Aerial surveys are not a feasible method in estimating mule deer abundance in landscapes characterized by extreme canopy cover associated with rugged terrain.

Secondary objectives were to estimate survival rates and determine cause-specific mortality factors along with calculating home range sizes and seasonal movements of mule deer. Due to the limited number of locations for the Meade-Pennington study area, locations were combined for home range analysis of 36 individual deer over the three years of the study. Female 95% annual home range size averaged 1,811 ha (SE=72.9, *n*=28). Male 95% annual home range size averaged 2,124 ha (SE=206.2, *n*=4). Summer home range size for females that displayed migratory behavior averaged 1,765 ha (SE=151.4, *n*=4). Winter home range size for females that displayed migratory behavior was not calculated because insufficient location data was available. Eleven seasonal movements were documented for female deer in the Meade-Pennington study area, with an average distance

of 7.4 km (SE=0.63, *n*=11). Minimum distance traveled between seasonal ranges was 5.2 km, and maximum distance was 11.7 km. Average spring departure date was 18 April (*n*=11) and ranged from 11 March to 26 May. Average fall departure date was 3 December (*n*=10) ranging from 15 August to 20 February. Within the FPNG study area, 95% annual home range size varied between years and averaged 3,317 ha (SE=148.4, *n*=22) in 2010, 2,189 ha (SE= 123.9, *n*=31) in 2011, and 1,952 ha (SE=108.2, *n*=26) in 2012. Individuals that displayed migratory behavior had a 95% summer home range size of 2,175 ha (SE=174.1, *n*=18) in 2010, 1,898 ha (SE=264.9, *n*=6) in 2011, and 1,974 ha (SE=552.5, *n*=7) in 2012. 95% winter home range size for female deer was 1,772 ha (SE=168.9, *n*=12) in 2010-11 and 2,293 ha (SE=423.1, *n*=5) in 2011-12. Average migration distance between summer and winter home ranges for 28 female mule deer was 13.1 km (SE = 1.9, *n*=28). Minimum distance traveled was 3.9 km, and maximum distance was 32.8 km. Spring median departure dates for 2010, 2011 and 2012 occurred on 7 April (*n*=13), 16 April (*n*=7) and 17 April (*n*=4), respectively, and ranged from 18 February to 28 May. In 2010-11, fall median departure date for migrating deer was 19 January (*n*=16), and ranged from 2 December to 16 February. In 2011-12, median fall departure date was 18 October (*n*=5) and ranged from 4 August to 29 December. Survival rates were determined for the Meade-Pennington study area for both male and female mule deer. Female annual survival rates during 2010, 2011 and 2012 were 0.89 (SE=0.049, *n* = 39), 0.71 (SE=0.071, *n* = 40) and 0.90 (SE=0.043, *n* = 49), respectively. Male annual survival rates during 2010 and 2011 were 0.56 (SE=0.165, *n* = 9) and 0.60 (SE=0.219, *n* = 5). In the FPNG study area, female annual survival rates during 2010, 2011 and 2012 were 0.77 (SE=0.060, *n* = 48), 0.76 (SE=0.063, *n* = 46) and 0.78 (SE=0.069, *n* = 36), respectively.

PREFACE

This report summarizes results of research conducted by South Dakota Department of Game, Fish and Parks personnel from January 2010 through February 2013 on determining and evaluating factors that affect sightability of mule deer during aerial surveys to develop a sightability model, and to determine home ranges, seasonal movements, and survival rates of mule deer in central and western South Dakota, under Pittman-Robertson project W-75-R-55, Study No. 7536.

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In the Fort Pierre National Grasslands study area, we received assistance tracking deer and aerial surveying from Nathan Baker, Andy Lindbloom, Randy Roede, Tim Withers, Corey Henderson, Bryce Ahlers, Keely McCormick, Andy Viet, Jason Burt, Maggie Lindsey, Keith Schwarz, and Nathan Poole. Special thanks goes out to our state pilot, Doug Jones, for his endless hours of flying during aerial surveys, and locating deer.

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INTRODUCTION

Aerial surveys are used to estimate the population size of large mammals; however, few surveys accurately count all animals, due mainly to visibility biases. Visibility bias can be defined as "the failure to observe all animals" which causes inaccuracies in aerial survey estimates (Caughley 1974, 1977). Caughley (1977) reported that aerial surveys failed to detect 12-71% of animals known to be present in a study area with flat and open terrain. Total counts of ungulate populations are not feasible and numerous aerial surveys have documented biases associated with underestimates of population size (Caughley 1974, LeResche and Rausch 1974, Floyd et al. 1979, DeYoung 1985). One approach used to correct for visibility bias of ungulate populations are sightability models (Samuel et al. 1987).

Sightability models are used to calculate the detection probability of individual groups and correct for groups missed during surveys by documenting factors affecting animal detection (Samuel et al. 1987). Models are developed by flying over groups of animals containing radio-collared individuals and by recording covariates for individual groups both observed and undetected by observers (Samuel et al. 1987). Numerous factors affecting sightabiltiy have been documented and include type of aircraft, speed, altitude, strip width, group size, group activity (i.e., bedded, standing, moving), observer experience, vegetative cover, canopy cover (i.e, visual obstruction), topography, and snow cover (Caughley 1974, Samuel et al. 1987, Otten et al. 1993, Bodie et al. 1995, Anderson et al. 1998, Cogan and Diefenbach 1998, Allen 2005, Jacques 2006, Krueger et al. 2007, Mcintosh et al. 2009, Rice et al. 2009, Walsh et al. 2009, Jarding 2010, Phillips 2011, Robling 2011).

Logistic regression models are used to determine predictor variables based on various group-specific and environmental covariates (Samuel et al. 1987, Walsh et al. 2009). Detection probabilities generated through sightability models assume individual groups do not have an equal probability of being detected and are estimated on a group by group basis (Pollock and Kendall 1987, Steinhorst and Samuel 1989, Anderson 1994). Model applicability depends on the environment (e.g., snow condition, canopy cover, speed, altitude, vegetative cover, group size) of future surveys (White and Shenk 2001) and the model cannot be used if future surveys do not reflect conditions that are similar to those experienced during model development.

Throughout South Dakota, numerous sightability models have been developed to estimate population size on large mammal species including elk (*Cervus elaphus*; Jarding 2010, Phillips 2011), white-tailed deer (*Odocoileus virginianus*; Robling 2011), mule deer and white-tailed deer combined (Grassel 2000), and pronghorn (*Antilocapra americana*; Jacques 2006). Although two deer sightability models have been developed in the Missouri River break region of central South Dakota and the agricultural landscapes that typify eastern South Dakota; no regression-based sightability model has been developed for mule deer occupying grassland and rugged river break habitats. Thus, our objectives were to construct logistic regression models to estimate mule deer sightability and evaluate factors contributing to visibility bias during spring and winter survey flights in the grasslands habitats of central South Dakota and the rugged river break habitats of western South Dakota.

Very limited information exists pertaining to seasonal movements and home range size of mule deer in the prairie regions of South Dakota. Understanding these movement strategies are important when considering current and future management unit boundaries. Knowledge about home range size during seasonal time periods is also an important aspect of deer management.

Grassel (2000) investigated home range sizes and movements of mule deer on the Lower Brule Sioux Reservation in central South Dakota. Severson and Carter (1978) investigated movements of mule deer in western South Dakota. However, these studies occurred in different geographical areas, representing different habitat characteristics. Griffin et al. (2005) studied mule deer home ranges and movements in the southern Black Hills and noted that factors affecting deer home ranges and movements included seasons, geographic regions, topography, climatic factors and distances traveled to fulfill daily and seasonal requirements. Other factors that may affect movements and home range size in South Dakota include distribution of habitat types, availability of agricultural lands interspersed amongst native range, and seasonal weather conditions. Similar research has been conducted on other mule deer populations throughout the western United States in determining home range size and movements (Pac et al. 1988, Wood et al. 1989, Kie et al. 2002).

Limited information exists regarding survival and cause-specific mortality factors on mule deer within South Dakota. Little is known about the survival of both male and female mule deer, and their major causes of mortality. Griffin et al. (2005) investigated cause-specific mortality in the southern Black Hills of South Dakota, and Grassel (2000) studied these factors on the Lower Brule Sioux Reservation on the Missouri River Breaks in central South Dakota. Other researchers have determined that survival estimates are critical in modeling calculations and formulating lambda. White and Bartmann (1983), Hamlin and Mackie (1989), Wood et al. (1989), and Unsworth et al. (1999b), studied female mule deer survival to better understand population characteristics. Carrel et al. (1999) studied mule deer survival along the Utah and Arizona borders, and McCorquodale (1999) documented survival rates for female black-tailed deer in Washington. Understanding annual survival rates of male mule deer are also important in

population management. No information exists regarding mule deer male survival rates in South Dakota; however, these rates have been investigated by Wood et al. (1989), McCorquodale (1999) Carpenter et al. (1979), Pac et al. (1988), Bleich and Taylor (1998), and Carrel et al. (1999) throughout the western United States and documented the leading cause of mortality among mule deer males was harvest mortality.

Because mule deer annual survival rates fluctuate annually and geographically within South Dakota, investigating these vital rates are important for the management of the species in South Dakota (Grassel 2000, Griffin et al. 2005). Knowledge of current survival rates and causes of mortality will assist managers in making informative management decisions, improve modeling techniques and provide an annual rate of change for mule deer populations occupying South Dakota. Information on survival and mortality factors are needed to better manage mule deer populations in all habitat types in western and central South Dakota. Thus, secondary objectives of this study were to estimate survival rates and determine cause-specific mortality factors along with calculating home range sizes and migration distances of mule deer occupying various habitat types within South Dakota.

OBJECTIVES

1. To determine and evaluate factors affecting sightability of mule deer during winter and spring green-up in western and central South Dakota.
2. To develop an aerial survey model for estimating population size of mule deer in western and central South Dakota.
3. To collect information on home range size and seasonal movements of mule deer in South Dakota.
4. To estimate survival rates and determine mortality factors of mule deer in South Dakota.

STUDY AREAS

Meade–Pennington Counties

The Meade and Pennington County study site encompassed approximately 600 km^2 in western South Dakota (44° N 102° W) (Figure 1). This study area consisted of lands made up of private, state and federal properties. The area is characterized by the Cheyenne River breaks with rough habitat consisting of deep wooded draws with scattered agricultural lands on the upper flat land areas. Land use included cattle grazing and agriculture. Topographic draws in the area were interspersed with Juniper (*Juniper spp*.) as the main cover. Natural vegetation consisted of blue grama (*Bouteloua gracilis*), western wheatgrass (*Agropyron smithii*) and buffalograss (*Buchloe dactyloides*) (Bryce et al. 1998). Agricultural crops on the flat uplands consisted mostly of dry land corn (*Zea mays*), wheat (*Triticum aestivum*), and grass/alfalfa (*meticago sativa*). Elevations ranged from 607 - 762 meters above sea level. The minimum and maximum mean temperatures for January are –19° C and -6° C, respectively. The mean July minimum and maximum temperatures are 14° and 31° C, respectively (Bryce et al.1998). Mean annual precipitation is 41-46 cm (Bryce et al. 1998).

Fort Pierre National Grasslands (FPNG)

The Fort Pierre National Grasslands study area consisted of a 1800 km^2 area located in central South Dakota just to the south of Pierre, South Dakota (44° N 100° W) (Figure 2). This study area consisted of the Fort Pierre National Grasslands (469 km^2), surrounded and interspersed with private land. The study area is characterized by rolling grasslands interspersed with agricultural lands. Very few wooded draws existed throughout the study area. Land use included cattle grazing and agriculture. Major agricultural crops in the area included wheat,

sunflowers (*Helianthus spp*), sorghum (*Sorghum bicolor*), and corn. Natural vegetation consisted of blue grama, western wheatgrass, smooth brome (*Bromus inermis*), little bluestem (*Schizachyrium scoparium*), buffalograss, and snowberry (*Symphoricarpos occidentalis*). Elevations ranged from 518 - 655 meters above sea level. The mean January minimum and maximum temperatures are –16° and -2° C, respectively. The mean July minimum and maximum temperatures are 16° and 33° C, respectively (Bryce et al. 1998). Mean annual precipitation is 38-43 cm (Bryce et al. 1998).

METHODS

To accomplish study objectives, three study segments were initiated: 1) capture and radio collar mule deer on two different study sites in South Dakota; 2) evaluate the feasibility of aerial deer surveys using a fixed wing aircraft: and 3) determine deer movements, subsequent home ranges, and survival. All study segments were completed as an internal research project through South Dakota Department of Game, Fish and Parks.

Capture

During January 2010 – March 2012, mule deer were captured in two different study sites in western and central South Dakota. Capture techniques included aerial net gunning from a Robinson-44 helicopter (Quicksilver Air, Peyton, Colorado, and Fairbanks, Alaska, USA). Deer were netted from the helicopter, restrained, blindfolded, sexed, and aged as yearling or adult. Antibiotics (i.e., penicillin) were administered subcutaneously in 2011 and 2012. Latitude and longitude coordinates and comments related to the capture were also recorded. Yearly captures were conducted to keep sample sizes of 50 individuals in both study areas during 2011 and only in the Meade-Pennington study area in 2012.

All deer were fitted with VHF (Very High Frequency) radio equipped neck collars (Telonics Inc, Mesa, Arizona, USA). Radiocollars were equipped with mortality sensors with a 4 hour inactivity delay for determination of mortality. Radiocollars also had colored bands (red, blue, and yellow) sewn onto the tops of the collars for assisting in identifying individual deer from the aircraft during sightability trials. Mule deer were released immediately after processing at the site of capture.

Sightability

Spring surveys were flown during peak spring green-up when potential color differences between sun-bleached deer and actively growing green vegetation were present. We conducted winter sightability trials in the Meade-Pennington County study area only when 100% snow cover was present. In the FPNG study area, winter surveys were flown when 100% snow cover was present and when no snow cover was present. Within both study areas, maps with up-to-date locations were constructed to determine where radio-collared individuals were located to maximize sampling efforts and eliminate unnecessary flight time.

All flights were flown using a Cessna 172 fixed wing aircraft. The telemetry operator, who was responsible for locating animals, delineating transect boundaries and recording data, sat in the back seat. Radio-collared individuals were located using (2) 4-element yagi antennas (Advanced Telemetry Systems, Inc., Isanti, MN) that were mounted to the wing struts. Two primary observers were present in the plane; one was positioned next to the pilot while the other was the pilot. Multiple primary observers were used for all sightability trials throughout model development in both study areas and their sole responsibility was to detect and count deer. We flew parallel north to south or south to north transects spaced at 800 m intervals over the survey area where the radio-collared deer were present. We determined transect widths using mapping

software (Garmin Map Source). The aircraft was flown at an altitude of approximately 45-60 m above the ground at speeds ranging from 125-145 km/hr.

When a mule deer group containing at least one radio-collared individual was observed, the search pattern was interrupted until all deer were counted and data recorded. We collected information on group size, activity, habitat, topography, and visual obstruction. If a radio-collared individual was not observed, the observers were notified after sampling efforts were completed for that immediate area and aerial telemetry equipment was used to locate the missed group. Once located, the same variables were recorded; however, when the group could not be found or visually observed, that group was censored from the trial. We recorded multiple radio-collared deer in a group as one observation because we defined our sampling unit as the group, not the individual (Samuel et al. 1987).

Activity of the group was recorded and categorized as 1 - active, 2 - standing, or 3 - bedded for the first individual seen. Habitat type for the winter and spring models were recorded and categorized as 1 – deciduous trees, 2- coniferous trees, 3 - wetland, 4 – tall grass, 5 – open and 6 – development. The habitat type occupied by the majority of the group was recorded. Topography was visually estimated around the site where the group was first detected and categorized as 1 – flat, 2 – draw shallow, 3 – draw medium, 4 – draw deep. Percent visual obstruction was visually estimated around the site where the deer group was first seen and the values of 0- (0%), 1- (1-25%), 2- (26-50%), 3- (51-75%), or 4- (76-100%) were assigned to calculate detection probabilities. Because measuring visual obstruction is subjective and can vary significantly between observers (Anderson 1994), we used example diagrams/pictures from Unsworth et al. (1999a) to minimize variability.

Sightability observations of deer were analyzed with logistic regression analysis using generalized linear modeling (GLM) in program R (R Development Core Team 2013). Models were evaluated and ranked using information-theoretic methods (Burnham and Anderson 2002). Groups of deer seen and missed were used as the response variable. Independent variables included group size, animal behavior, habitat type, topography and percent visual obstruction. The detection probability model used in the analysis for predicting sightability was:

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

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

Home range and movements

Radio-collared deer were located from the ground and/or the air as often as possible from February 2010 through October 2012 in the Meade-Pennington study area and through December 2012 in the FPNG study area. Ground locations were collected using a vehicle mounted "null-peak" antenna system (Brinkman et al. 2002). We took two to four directional bearings from established telemetry stations for each location. We used an electronic digital compass (C100 Compass Engine, KVH Industries, Inc., Middletown, RI, USA; Cox et al. 2002) that was connected to the mast of the null-peak antenna system to generate directional bearings; this unit had an estimated azimuth accuracy of +/-1°. We entered bearings into the LOCATE III computer program (Nams 2006) to estimate locations and error polygons. Aerial locations were collected using a Cessna 172 airplane equipped with wing mounted 2-element H-antennas. Due to the proximity and the lack of roads in the study areas, most locations obtained were collected

via aircraft. Locations of deer that were visible from the air were recorded using GPS units. If visual observations were not possible, deer were located using a null-peak switch box from the aircraft. All locations of radio-collared deer were assigned either Universal Transverse Mercator (UTM) coordinates or latitude-longitude in decimal degree. Aerial location error polygons were assessed by tracking transmitters placed at fixed locations. Estimated locations from numerous fixed transmitters were then compared with actual locations to derive the mean linear error. The radius of the error circle was then calculated using the formula:

$$\text{Radius} = \text{mean linear error} + (1.96)\ (\text{SE of mean linear error})$$

The area of the error circle was then calculated using the formula πr^2 (Seddon and Maloney 2004). Compiled locations of individual deer were analyzed to determine home range size and if the deer exhibited migratory behavior, or was classified as a resident.

Every attempt was made to obtain weekly locations on individual deer to maximize sample size. However, mortality of deer, scheduling conflicts, and other factors affected location sample size objectives on some individuals. Therefore, home ranges were only calculated for deer with 20 or more locations on annual, winter or summer ranges. Deer locations in the Meade-Pennington study area were combined over the 3-year study to increase sample size. Deer locations in the FPNG study area were analyzed on a yearly basis to determine annual, winter, and/or summer home ranges. Home range size, departure dates from seasonal home ranges, migration distances, and trends were determined through use of locations obtained from radio-collared animals.

We imported locations into ArcMap 10.0 (ESRI, Inc., Redlands, CA) and used the statistical package R with adehabitatHR, shapefiles and maptools (R Core Team 2012). A 95% kernel utilization distribution with a smoothing parameter of 550 was used. We calculated

seasonal migration distance by measuring the straight-line distance between harmonic means of seasonal home ranges (Nicholson et al. 1997). Deer were considered migratory if no overlap existed between seasonal home ranges (Nelson 1995). We calculated migration date as the mean date of departure between consecutive locations on separate seasonal ranges (Nelson 1995). We classified animals as obligate migrators if they migrated annually between seasonal home ranges and resided there until the following migratory period occurred (Brinkman et al. 2005, Burris 2005, Grovenburg et al. 2009). We classified deer as conditional or facultative migrators (Nelson 1995) if they failed to migrate during a documented migratory period or made several trips between seasonal home ranges and occupied that home range for <1 month (Brinkman et al. 2005). We classified deer as residents if they failed to migrate and had overlapping seasonal home ranges. Spring migration was classified as movement from winter to summer ranges and fall migration was classified as movement from summer to winter ranges. We used ANOVA to compare home range sizes and migration distances of radio-collared deer between years, sexes and seasons (Zar 1999).

Survival

Weekly survival monitoring was conducted from February 2010 thru February 2013 in conjunction with locating radio-collared deer. Mortalities were determined based on the pulse rate that was being emitted from the radiocollar. Normal radiocollar pulse rates were 60 pulses per minute (ppm), and the mortality sensor on the radio collars was 120 ppm. Upon hearing a mortality signal from a radio-collared deer, the deer was located from the ground as soon as possible to collect cause-specific mortality information. Evidence of *Canid* presence was determined by tracks, scat and the condition of the carcass. However, some deer were not recovered soon enough to determine cause-specific mortality. Mortalities were also reported

from hunters after radio-collared individuals were harvested. When deer went missing over the hunting season, and the collars were not reported, South Dakota Game, Fish, and Parks (SDGFP) sent out an e-mail to all hunters in the respective hunting units asking if any deer with radiocollars were harvested. Mule deer were censored from survival analysis if they died within two weeks of capture or disappeared from the study area and were never relocated.

We calculated annual survival rates (1 February- 31 January) for both males and females using the Kaplan-Meier method (Kaplan and Meier 1958) adapted for staggered entry (Pollack et al. 1989) in Program MARK version 6.0 (White and Burnham 1999, Cooch and White 2006).

Winter severity index

We calculated winter severity indices (WSI) for the Meade-Pennington and FPNG study areas during the winters of 2009-10, 2010-11, 2011-12 and 2012-13. We calculated WSI values using mean monthly air temperatures in degrees Celsius (temp) and total monthly snowfall in centimeters (Snow) in the following manner:

- if temp ≤ -20, then WSI = 4x Snow
- if temp > -20 and ≤ -10, then WSI = 3x Snow
- if temp > -10 and ≤ 0, then WSI = 2x Snow
- if temp > 0, then WSI = 1x Snow

Temperature and snowfall data were quantified monthly from November through April to determine the total WSI for each year (Baccante and Woods 2010).

RESULTS

Capture

From January 2010 - March 2012, 128 adult female mule deer and 10 adult male mule deer were captured and radio-collared (*n*=78, Meade-Pennington Counties; *n*=60, Fort Pierre National Grasslands (FPNG) Appendix A, B). On 26 January 2010, a total of 40 adult female mule deer, and 10 adult male mule deer were captured in the Meade-Pennington study area. On 28 January 2010, a total of 50 adult female mule deer were captured in the FPNG study area. Capture of additional deer occurred on 21 February, 2011, with 8 adult females in the Meade-Pennington study area, and 10 females in the FPNG study area. On 29 February 2012 and 1 March 2012, an additional 20 adult females were captured in the Meade-Pennington study area. Over the three years, one adult female died during capture operations during the 2012 capture event in the Meade-Pennington study area.

Sightability

Meade-Pennington Counties

Spring

Within the Meade-Pennington study area we conducted spring sightability flights from 7-16 April 2010 and 9-25 April 2012 on 45 radio-collared deer in 2010 and 52 radio-collared deer in 2012. We recorded a total of 107 sightability observations during 9 flights; however, canopy cover reduced visibility of deer and resulted in 61 observations censored from analysis because groups that were missed could not be detected. Thus, 46 observations were used for model development (Table 1). We observed 10 of 107 (9.3%) deer groups and missed 97 of 107 (90.7%) groups. Of the groups that were detected (*n*=46), average group size was 4.6 deer and 65.2% of detected deer groups were observed in trees (Table 1).

Thirteen different models that all included canopy cover and different combinations of other predictor variables were analyzed (Table 2). The AICc best selected model included the independent covariate % canopy cover (Table 2). However, the w_i value for the top model was 0.247 (Table 2) and the p-value for the intercept value was not significant ($p \geq 0.05$; Table 3). Thus, no statistically significant model was developed for the spring in the Meade-Pennington County study area.

Winter

Winter sightability flights within the Meade-Pennington study area were flown between 26 February to 17 March 2010 and 12 January to 24 March 2011 on 46 radio-collared deer in 2010 and 39 radio-collared deer in 2011 when 100% snow cover was present. We recorded a total of 109 sightability observations during 11 flights; however, 29 groups that were missed could not be detected and were censored from analysis. Thus, 80 observations were used for model development (Table 4). We observed 34 of 109 (31.2%) deer groups and missed 75 of 109 (68.8%) groups. Of the groups that were detected (n=80), average group size was 15.3 deer and 44.4% of detected deer groups were observed in trees (Table 4).

Thirteen different models that all included canopy cover and different combinations of other predictor variables were analyzed (Table 5). The AICc best selected model included independent covariates % canopy cover and group size (Table 5). However, the w_i value for the top model was 0.284 (Table 5) and the p-values for the intercept and group size were not significant ($p \geq 0.05$; Table 6). Thus, no statistically significant model was developed for the winter in the Meade-Pennington County study area.

FPNG

Spring

Spring flights were flown in the FPNG area between 7-22 April 2010, 6-27 April 2011, and 17-30 April 2012 on 45 radio-collared deer in 2010, 43 radio-collared deer in 2011 and 35 radio-collared deer in 2012. We recorded a total of 253 sightability observations during 14 flights and no observations were censored from analysis. Thus, 253 observations were used for model development (Table 7). We observed 167 of 253 (66%) deer groups and missed 86 of 253 (34%) groups. Of the groups that were detected (n=253), average group size was 9.57 deer and 94.05% of detected deer groups were observed in open habitat (Table 7).

Seven different models that included different combinations of predictor variables; group size, activity, and topography were analyzed (Table 8). The AICc best selected model included independent covariates of group size, activity and topography (Table 8). The w_i value for the top model was 0.902 (Table 8) and the p-values for all coefficients were significant ($p \leq 0.05$; Table 9). Thus, a significant model was developed for the spring in the FPNG study area. The logistic regression portion of the top model was:

$$y = 2.982 + 0.067(\text{group size}) - 0.865(\text{activity}) - 0.568(\text{topography})$$

Increased group size, increased activity, and flatter terrain all increased the detection probability of observing deer (Table 7).

Winter (100% Snow Cover)

We conducted winter sightability flights over 48 radio-collared deer between 3-24 February 2010, 37 radio-collared deer between 1 January to 9 February 2011 and 36 radio-collared deer on 1 March 2012, when 100% snow cover was present. We recorded a total of 298 sightability trials during 13 flights (Table 10). We observed 252 of 298 (84.6%) deer groups and

missed 46 of 298 (15.4%) groups. Average group size during the winter when there was 100% snow cover was 21.5 deer and 90.6% of all deer groups were observed in open habitat (Table 10).

Seven different models that included covariates of group size, activity, and topography were analyzed (Table 11). The AICc best selected model included independent covariates of group size and topography (Table 11). The w_i value for the top model was 0.58 (Table 11) and the p-values for all coefficients were significant ($p \leq 0.05$; Table 12). Thus, a significant model was developed for the winter when 100% snow cover was present. The logistic regression portion of the top model was:

$$y = 2.363 + 0.054(\text{group size}) - 0.742(\text{topography})$$

Increased group size and flatter terrain both increased the detection probability of observing deer (Table 10).

Winter (No Snow Cover)

Winter flights, when no snow cover was present, were flown in the FPNG study area between 14-29 December 2011 and 13-14 February 2012 over 43 radio-collared deer in 2011, and 35 radio-collared deer in 2012. We recorded a total of 94 sightability trials during 8 flights (Table 13). We observed 55 of 94 (58.5%) deer groups and missed 39 of 94 (41.5%) groups. Average group size during the winter when no snow was present was 8.14 deer and 79.8% of all deer groups were observed in open habitat (Table 13).

Fifteen different models that included covariates group size, activity, topography and canopy cover were analyzed (Table 14). The AICc best selected model included independent covariates group size, activity, topography and canopy cover (Table 14). The w_i value for the top model was 0.64 (Table 14) and the p-values for all coefficients were significant ($p \leq 0.05$; Table

15). Thus, a significant model was developed for the winter when no snow cover was present. The logistic regression portion of the top model was:

y= 9.509 + 0.184(group size) – 2.444(activity) – 2.132(topography) – 0.603(canopy cover)

Increased group size, higher activity levels, less canopy cover, and flatter terrain all increased the detection probability of observing deer (Table 13).

Home range

Locations were obtained in the Meade-Pennington study area 2-3 times per month. Locations were obtained in the FPNG study area approximately 1-2 times per week utilizing the SDGFP state airplane.

A total of 2,212 locations were obtained for the Meade-Pennington study area, and a total of 7,985 locations were obtained in the FPNG study area with a calculated error polygon of 0.78 hectares. Individuals with <20 locations on annual, winter or summer home ranges were excluded from the analysis. Thus, home ranges were calculated for 36 individual deer in the Meade-Pennington study area, and 51 individual deer in the FPNG study area.

Meade-Pennington Counties

Location data collected from 2010-2012 in the Meade-Pennington study area was combined for all years due to the lack of annual locations to adequately determine home ranges. Annual 95% home range size for females averaged 1,811 ha (SE=75.7, n=28). Annual 95% home range size for adult males averaged 2,124 ha (SE=206.2, n=4). Summer 95% home range size for females averaged 1,765 ha (SE=117.4, n=4). No winter home ranges were calculated for the Meade-Pennington study area due to the lack of adequate locations for analysis. We calculated home ranges using a minimum of 20 and a mean of 42.9 (SE=1.7, n=36) locations. Annual home range size between adult female and adult male mule deer were not significantly

different (P=0.229) in the Meade-Pennington study area. Pooled home range size for all females and males averaged 1,841 ha (SE=64.1, n=36).

FPNG

Home range sizes for female mule deer in the FPNG study area were determined annually from 2010-2012. Annual home ranges were calculated for deer that displayed no movements between seasonal ranges for that year. Some individuals exhibited migratory behavior annually and moved to winter and summer home ranges. Yearly variations were also evident in individual deer that stayed on an annual home range in one year and then exhibited migrational movements to summer and winter ranges in other years.

We calculated individual home ranges using a minimum of 20 and a mean of 57.7 (SE=1.7, n=127) locations. Annual 95% home ranges in 2010, 2011, and 2012, were 3,317 ha (SE=148.4, n=22), 2,189 ha (SE=123.9, n=31), and 1,952 ha (SE=108.2, n=26), respectively. Annual ranges in 2010 differed from annual ranges in 2011 (P<0.0001) and 2012 (P<0.0001). Annual home ranges were similar in 2011 and 2012 (P=0.17). In summer, 95% home ranges averaged 2,175 ha (SE=174.1, n=18) in 2010, 1,898 ha (SE=264.9, n=6) in 2011, and 1,974 ha (SE=552.5, n=7) in 2012. No statistical difference existed between 2010 and 2011 summer home ranges (P=0.44); 2011 and 2012 summer home ranges (P=0.91); and between 2010 and 2012 summer home ranges (P=0.65). Pooled summer home range size throughout the three year study averaged 2,076 ha (SE=162.8, n=31). In winter, 95% home range size in 2010-11 and 2011-12 averaged 1,772 ha (SE=168.9, n=12) and 2,293 ha (SE=423.1, n=5), respectively. Mean home range size was similar between winter of 2010-2011 and 2011-2012 (P=0.18). Thus, the pooled winter home range size averaged 1,925 ha (SE=174.8, n=17).

Movements

Meade-Pennington Counties

Within the Meade-Pennington area, four deer (10.3%) exhibited conditional migratory behavior and seven deer (17.9%) exhibited obligate migratory behavior. The majority of mule deer (71.8%; *n*=28) were classified as residents and stayed on an annual home range throughout the duration of the study. Of the eleven deer that displayed migratory behavior, we documented an average migration distance of 7.4 km (SE=0.63, *n*=11). Minimum migration distance traveled was 5.2 km, and maximum distance was 11.7 km. Winter to summer departure dates from seasonal home ranges were documented over the 3-year study period, and the average date of movement was 18 April (*n*=11) ranging from 11 March to 26 May. Median departure date from summer to winter ranges was 3 December (*n*=10) ranging from 15 August to 20 February.

FPNG

Forty-five percent (*n*=23) of mule deer occupying the FPNG study area were classified as residents and used an annual home range throughout the duration of the study, 35.3% (*n*=18) were classified as conditional migrators and occupied an annual home range at some point throughout the study along with displaying migratory behavior, and 19.6% (*n*=10) were classified as obligate migrators displaying migratory behavior annually. Of the 28 deer that displayed migratory behavior, we documented an average migration distance of 13.1 km (SE = 1.9, *n*=28). Minimum distance traveled was 3.9 km, and maximum distance traveled was 32.8 km. Median departure dates from winter to summer ranges was 7 April (*n*=13) ranging from 18 February to 28 May in 2010, 16 April (*n*=7) ranging from 23 March to 18 May in 2011, and 17 April (*n*=4) ranging from 29 March to 9 May in 2012. Timing of migrational movements in 2010-2012 were not significantly different (2010, 2011; *p*=0.48), (2011, 2012; *p*=0.91) and

(2010, 2012; p=0.52). The pooled average spring departure date was 12 April (n=24). Median departure dates from summer to winter home ranges was 19 January (n=16) ranging from 2 December to 16 February in 2010-2011, and 18 October (n=5) ranging from 4 August to 29 December in 2011-2012. Timing of migrational movements in 2010-11 and 2011-12 were significantly different ($p \leq 0.03$).

Survival

Meade-Pennington Counties

During 2010, one female and one male were censored from analysis due to capture related mortality, and disappearance from the study area. During 2011, one female was censored due to unknown fate, and during 2012 one female was censored due to unknown fate. During the 36 month study period, 28 deer died overall. Nine mortalities (4 males, 5 females; 32%) were due to hunter harvest mortality. Three mortalities (1 male, 2 female; 11%) were classified as natural mortality (e.g., coyote predation), and 16 mortalities (2 male, 14 female; 57 %) were classified as unknown; due to the inability to recover carcasses in adequate time to determine cause of death. Most of the unknown mortalities were suspected to be winter related or predation by coyotes.

Survival rates were determined for the Meade-Pennington study area for both male and female mule deer. Female annual survival rates during 2010, 2011 and 2012 were 0.90 (SE=0.049, n = 39), 0.71 (SE=0.071, n = 40) and 0.90 (SE=0.043, n = 49), respectively (Table 16). The three year pooled annual survival rate was 0.835 (SE=0.033, n=128); however, significant differences existed in annual survival rates of adult females among years (p<0.05). Male annual survival rates during 2010 and 2011 were 0.56 (SE=0.165, n = 9) and 0.60 (SE=0.219, n = 5) (Table 17).

FPNG

During 2010, two females were censored due to capture myopathy, and disappearance from the study area. During the 36 month study period, 30 deer died overall. Ten mortalities (33%) were due to hunter harvest mortality. Two mortalities (7%) were classified as vehicle collisions. Nine mortalities (30%) were classified as natural (e.g., coyote predation), and 9 mortalities (30%) were classified as unknown, due to the inability to recover carcasses in adequate time to determine cause of death. Most of the unknown mortalities were suspected to be winter related or predation by coyotes. Survival rates for female mule deer were determined for the FPNG study area. Female annual survival rates during 2010, 2011 and 2012 were 0.77 (SE=0.061, n = 48), 0.76 (SE=0.063, n = 46) and 0.78 (SE=0.069, n = 36) (Table 18). No significant differences were found in annual survival rates of adult females among years (P>0.05): thus, the three year pooled annual survival rate was 0.777 (SE=0.037, n=130).

Winter Severity Index

In the Meade-Pennington County study area, WSI values during 2009-2010 (132.0), 2010-2011 (239.7), 2011-2012 (70.9) and 2012-2013 (107.4) varied significantly among years (p>0.05). Within the FPNG study area, WSI values during 2009-2010 (257.9), 2010-2011 (391.7), 2011-2012 (129.1) and 2012-2013 (250.4) varied significantly among years (p>0.05). The winter of 2010-2011 was the most severe in both study areas.

DISCUSSION

Sightability

Within the Meade-Pennington County study area, we determined that aerial surveying in both spring and winter using a fixed-wing aircraft is not a feasible method due to terrain ruggedness and dense coniferous canopy cover (Table 1 and 4). The combination of these two environmental conditions resulted in winter sightability rates < 32% and spring sightability rates < 10%. Similar results were documented by Haffley (2013) in southeastern South Dakota, where sightability rates were <10% in areas characterized by steep terrain and dense coniferous canopy cover. Robling (2011) documented that canopy cover had the greatest influence on deer sightability in northeastern South Dakota. However, trees covered < 3% of the landscape, which resulted in winter sightability rates > 84%. Furthermore, canopy cover had the greatest effect on elk sightability during helicopter surveys in Michigan (Otten et al. 1993), South Dakota (Jarding 2010; Phillips 2011), Idaho (Samuel et al. 1987) and Pennsylvania (Cogan and Diefenbach 1998). Likewise, Anderson and Lindzey (1996) noted that percent canopy cover was the only significant predictor of moose sightability during helicopter surveys in Wyoming.

On the contrary, deer sightability models developed by Ackerman (1988) in Idaho and Grassel (2000) in central South Dakota found that canopy cover was not a significant factor in predicting mule deer and white-tailed deer sightability. We speculate that our results were contrary to Grassel (2000) because rangeland comprised approximately 82% of the landscape and canopy cover was limited to small, disjunct patches of eastern red cedar (*Juniperus virginiana*) in the Missouri River Breaks Region of central South Dakota. Also, Ackerman (1988) noted that model results may have been affected by variable measuring techniques among

observers because canopy cover was measured vertically even though most deer were spotted from an oblique angle. Unsworth et al. (1999a) emphasized that percent canopy cover should be measured obliquely and the use of trained, consistent observers was critical for determining its effect on deer sightability.

The intensity of canopy cover within the Meade-Pennington study area prevented us from locating missed groups and on numerous occasions missed groups had to be censored from analyses because we were unable to observe deer and collect information on important variables (e.g., group size). As a result, limited observations were available for model development and no significant models were formulated. In conclusion, fixed-wing aerial surveys for mule deer cannot be performed in areas characterized by extreme coniferous canopy cover associated with steep terrain.

Within the FPNG study area, we determined that group size, topography and activity were the three primary factors influencing mule deer sightability in the prairie landscapes of central South Dakota. Our findings indicated that the number of deer in a group had the greatest influence on mule deer sightability. Group size was significant ($p \leq 0.05$) in all top models for spring and winter and had the greatest influence on sightability during winter when deer were in large herds (i.e., > 10 individuals). These findings were similar to those reported by Robling (2011), where group size was positively correlated to the probability of detecting deer in both spring and winter models. Cook and Jacobson (1979) and Samuel and Pollack (1981) both noted that group size significantly influenced ungulate sightability. Unsworth et al. (1999a) suggested that ungulate surveys should be conducted when group sizes are at a maximum.

Moreover, Gassaway et al. (1985) noted that sightability of moose increased greatly when they were in larger groups. Group size and activity significantly influenced the probability of

observing deer in Idaho (Ackerman 1988) and central South Dakota (Grassel 2000). In addition, Jacques (2006) reported that group size was strongly related to the probability of detecting pronghorn groups during spring aerial surveys in western South Dakota. However, group size did not influence elk sightability in Michigan (Otten et al. 1993) potentially because large (> 30) elk groups were not common. Likewise, Bodie et al. (1995) found that group size did not influence the probability of observing bighorn sheep and noted that high levels of sightability in open terrain and behavioral adaptations of disturbed bighorn sheep may have limited the effects of group size on sightability.

Topography (i.e., terrain ruggedness) also significantly influenced mule deer sightability during spring and winter trials. Topography within the FPNG was mostly characterized by riparian drainages with moderate topographic variation. However, deer observed on flat terrain had higher detection probabilities compared to those observed in medium to deep draws. These findings were similar to Jacques (2006), where topography was the most influential variable in predicting pronghorn sightability in northwestern South Dakota. Likewise, Bodie et al. (1995) reported that topography greatly influenced bighorn sheep sightability in Idaho and noted that bighorn sheep on flat open slopes were more visible then those occupying rugged terrain. However, terrain ruggedness was not a significant factor in a study conducted on mule deer sightability in Idaho (Ackerman 1988). Phillips (2011) documented similar results, and noted that terrain ruggedness had no effect on elk sightability in the Black Hills of South Dakota.

Group activity (i.e., bedded, standing, moving) was not significant in the 100% snow model; however, activity significantly ($p \leq 0.05$) influenced sightability in the spring and winter no snow model. Deer that were moving or standing had an increased probability of detection compared to bedded deer (Table 7, 13). However, the probability of observing moving deer was

not greater than the probability of observing standing deer. Deer sightability models developed by Ackerman (1988) and Grassel (2000) documented group activity was a significant factor affecting sightability where canopy cover was a limited factor. Zabransky (2011) noted mule deer sightability in western Texas was highly influenced by group activity. Bodie et al. (1995) reported that in open terrain, moving groups of bighorn sheep were twice as likely to be detected compared to stationary sheep. Allen (2005) and Mcintosh et al. (2009) reported that elk groups exhibiting limited activity negatively influenced detection rates in Canada. Jacques (2006) reported group activity was the most influential factor in predicting pronghorn sightability in southwestern South Dakota where the effect of canopy cover was limited. We speculate group activity was only a significant factor in the spring and winter no snow model because when 100% snow cover was present, detection rates increased significantly, making deer easier to detect regardless of group activity.

Because variation in snow conditions can influence detection probabilities of ungulates during aerial surveys (LeResche and Rausch 1974, Leptich and Zager 1992), we conducted winter sightability trials when 100% snow cover was present or when no snow was present to mitigate this potential snow effect. We estimated that winter detection rates with 100% snow cover were 26.1% higher compared to winter detection rates with no snow. Thus, snow cover greatly influenced sightability rates of mule deer occupying open prairie landscapes within central South Dakota, resulting in less variability within population estimates.

Home Range and Movements

Meade-Pennington Counties

The majority of mule deer (71.8%) in the Meade-Pennington study area did not exhibit migratory behavior and were classified as residents. These results were similar to those reported

by Kufeld et al. (1989) within the Rocky Mountain foothills of Colorado, where 93% were classified as residents. Likewise, 81% of radio-collared mule deer in the sagebrush-steppe region of south-central Washington displayed non-migratory behavior (Eberhardt et al. 1984). However, Wood et al. (1989), reported only 29% of radio-collared adult females in the prairies of eastern Montana were classified as residents. Research conducted in southeastern Idaho reported only 26% of marked individuals were non-migratory (Brown 1992). Research conducted by Carrel et al. (1999) in Arizona documented only 4.5% of marked individuals were classified as residents. Grassel (2000), reported that >85% of radio-collared mule deer in the Missouri River breaks of central South Dakota displayed migratory behavior.

Garrott et al. (1987) noted that seasonal movement patterns demonstrated by migratory mule deer are most likely driven by the quality and quantity of available forage within that individual's home range and by seasonal changes influencing energetic needs. Animals likely select and use resources that satisfy life requirements and if these suitable resources are not available; animals will likely migrate and move to areas that can satisfy these requirements (Fagen 1988). We speculate that the majority of mule deer occupying the Meade-Pennington study area did not display migratory behavior because these essential life requirements were met within that occupied home range. Grassel (2000) documented that winter ranges in central South Dakota were characterized by topographic breaks and draws that were adjacent to agricultural crop fields. Likewise, the Meade-Pennington study area was characterized by river breaks consisting of deep wooded draws with scattered agricultural lands on the upper flat land areas; thus making this ideal winter and summer habitat. As a result, we found a high percentage of resident deer within this area.

Within the Meade-Pennington study area, of the deer that did display migratory behavior (*n*=11), we documented a similar mean migration distance (7.4 km) compared to recent work in central South Dakota (4.5 km; Grassel 2000) and the prairies of eastern Montana (5.9 km; Wood et al 1989). However, reported mean migration distances in other studies were greater. Griffin et al. (2005) recorded a mean migration distance of 16 km between seasonal ranges for female mule deer in the southern Black Hills. In northwest Colorado, Garrott et al. (1987) noted mean migration distances were 27 and 43 km for two different study areas. Mean migration distance of 40 km was recorded by Loft et al. (1989) in California. Thomas and Irby (1990) in southeastern Idaho detected average distances of 56 km for females. Likewise, Brown (1992) documented mean distances of 19.9 km for female mule deer in southeastern Idaho. Nicholson (1995) found that average migration distances varied for California mule deer that resided at different elevation levels and documented mule deer that resided below 1500 m elevation migrated an average of 12.6 km (range 8.6 to 19.8 km), and deer that resided above 1500 m in elevation migrated an average of 8.1 km (range 4.4 to 11.3 km). Carrel et al. (1999) studied mule deer in Utah and Arizona and noted average migration distances of 50.9 km and 22.6 km.

Mule deer populations associated with interior mountainous habitats have been known to demonstrate longer migration distances because snowfall limits access to forage at higher elevations (Thomas and Irby 1990). Thus, deer occupying mountainous terrain are forced to travel longer distances to avoid deep snow in order to find quality forage (Garrot et al. 1987). This migration strategy does not apply to deer occupying the Meade-Pennington study area because snow depth rarely affects forage availability. We speculate mule deer that did migrate in the Meade-Pennington area traveled shorter distances because suitable forage and cover was readily available.

Median spring departure date (18-April) for migratory deer in the Meade-Pennington area was similar to dates (10-April, and 29-March) documented by Grassel (2000) in central South Dakota. Likewise, Garrott et al. (1987) noted spring migration occurred from April to mid-June in northwest Colorado. In Montana, Wood et al. (1989) stated that spring migrations occurred in late-March to early April. Thomas and Irby (1990) reported variation existed among years in southeastern Idaho, and generally occurred between March-May. Kucera (1992) reported that the median spring departure date in California was 21 April. Nicholson (1995) reported mean dates of 10 April, 29 April, and 1 May over a 3 year period in California. Carrel et al. (1999) noted spring departure in Arizona occurred in late March with completion of migration by mid-May. However, later dates were reported by Griffin et al. (2005), indicating spring migration in the southern Black Hills of South Dakota occurred between mid to late-May. Annual variation in precipitation and temperature influences timing of spring migrations (Robling 2011) and deer likely demonstrated migratory behavior within the Meade-Pennington area when spring green-up occurred.

Median fall departure dates (3 December) were similar to research conducted in eastern Montana (Wood et al. 1989; mid-October to late-December). Furthermore, Griffin et al. (2005) indicated most deer occupied winter ranges by the end of November, which was similar to other research conducted across the west (Thomas and Irby 1990, Kucera 1992, Carrel et al. 1999). However, Grassel (2000) in south-central South Dakota noted mean fall migration dates of 3 October, 30 September, and 11 October. Within the Meade-Pennington area, October average temperatures in 2010 and 2011 were 2.7° and 2°C above the 30-year average, respectively (National Climatic Data Center 2013). Thus, slightly later departure dates may have been attributed to the mild fall weather that occurred during the study.

Mean annual 95% home range size in the Meade-Pennington study area was 1,811 ha for females and 2,124 ha for males. Male and female home range sizes were not significantly different, and were smaller compared to other studies conducted across the western states. Eberhardt et al. (1984) documented annual home range size of female (3,780 ha) and male (4,640 ha) mule deer in the sagebrush steppe region of south central Washington, and also noted no significant difference between males and females. In contrast, Hamlin and Mackie (1989) noted smaller annual home ranges for mule deer females (520 ha), and larger annual home ranges for mule deer males (2,700 ha) in the Missouri river breaks of Montana. Relyea et al. (2000) found that the home range size of males was more than twice that of females in southwest Texas; however, male home range size decreased with increased habitat productivity and unlike males, home range size of females showed no relationship with habitat productivity. Mackie et al. (1998) noted that deer occupied single yearlong home ranges because the basic requirements of maintenance and reproduction could be satisfied within that area. As a result, seasonal requirements were dispersed throughout that area and a deer could generally occur in any portion of the resident home range at any time of the year. Although factors that influence home range size were not specifically evaluated, we speculate that habitat quality in our study area along with the juxtaposition of wooded draws and agricultural fields allowed mule deer to maintain resident home ranges. Both male and female mule deer were able to find suitable habitat in an area that fulfilled needs for both summer and winter time periods, and thus both male and female mule deer occupied similar sized home ranges.

Within the Meade-Pennington study area, we calculated summer home range size on four female mule deer that exhibited migratory behavior. We were, however, not able to determine home range size on winter ranges due to the lack of sufficient locations. Average summer home

range size for female mule deer that displayed obligate migratory behavior in the Meade and Pennington study area was 1,765 ha, and was not significantly different compared to individuals that occupied annual home ranges. However, summer home range sizes of migratory deer in the Meade-Pennington study area were greater than summer home ranges reported in other studies. Mule deer summer home ranges were reported in Montana (Pac et al. 1988, 140-640 ha; Hamlin and Mackie 1989, 590 ha; Wood et al. 1989, 52-615 ha; Nicholson 1995, 554 ha), California (Loft et al. 1989; 40-200 ha; Kie et al. 2002, 664 ha), Idaho (Milner and Unsworth 1996; 891-1,216 ha), central South Dakota (Grassel 2000, 624 ha), and 354 ha in the Southern Black Hills of South Dakota (Griffin et al. 2005). We speculate that the four deer in the Meade-Pennington study area that did occupy a specific summer range utilized a larger area because of the juxtaposition of essential life requirements (i.e., food, water and cover); however, the lack of locations used to quantify home range size may have not provided a true representation of summer home range size. Variations among home range sizes across the country are likely explained by the broad differences of habitat characteristics different home ranges encompass and we speculate that deer living in areas characterized by open habitats (i.e., no cover) likely have larger home ranges than deer residing in areas characterized by dense vegetative cover.

FPNG

Deer within the FPNG study area displayed mixed movement strategies. In 2010, 2011, and 2012, the percentage of deer that occupied an annual home range were 55%, 83.8%, and 78.8%, respectively. However, when analyzing movement strategies across a 3-year period (2010-2012), 45.1% (*n*=23) were classified as residents and used an annual home range throughout the duration of the study, 35.3% (*n*=18) were classified as conditional migrators and occupied an annual home range at some point throughout the study along with displaying

migratory behavior, and 19.6% (*n*=10) were classified as obligate migrators displaying migratory behavior annually. Mixed movement strategies were demonstrated in both study areas; however, the percentage of resident deer (45.1%), in the FPNG study area, was considerably lower compared to deer occupying the Meade-Pennington County study area where 71.8% were classified as residents. Mixed movement strategies were also reported in the prairies of eastern Montana where 29% of radio-collared adult females were classified as residents (Wood et al. 1989). Research conducted in southeastern Idaho reported only 26% of marked individuals were non-migratory (Brown 1992). Research conducted by Carrel et al. (1999) in Arizona documented only 4.5% of marked individuals were classified as residents. Grassel (2000), reported that >85% of radio-collared mule deer in the Missouri River breaks of central South Dakota displayed migratory behavior.

Contrary to the Meade-Pennington study area, we speculate that mule deer occupying the FPNG study area displayed greater migratory behavior as a result of some areas not providing the essential life requirements within that occupied home range. Agricultural lands were scattered throughout the study area, and with phenological changes to croplands and native range, deer movements to more favorable habitat types were likely initiated. Mackie et al. (1998) noted that livestock grazing, land use disturbance, and predation were environmental variables that influenced the amount and effectiveness of reproductive and maintenance habitat available to mule deer and changes to these environmental covariates likely influenced movement.

The presence of predators (e.g., coyotes) may have been a contributing factor to these mixed movements strategies especially in the FPNG study area because escape cover was a limiting factor. Aerial anecdotal observations indicated coyotes occupied the majority of the

study area and on multiple occasions observed densities appeared to be high. Constant disturbance from predators may have forced some individuals to vacate annual ranges resulting in mixed movement strategies. Geist (1981) noted that mule deer are very reactive to disturbance and move to areas where predators are not present. Similar findings were reported by Altendorf et al. (2001) and reported that mule deer altered their foraging behavior to minimize predation risk. Mackie et al. (1998) theorized that movement patterns arise in the process of deer adapting to the environments they are exposed too. Furthermore, the type of movement strategy demonstrated by individual deer depends on the spatial arrangement of the habitat they attempt to exploit and are performed to allow individuals to efficiently use all available resources within in area, in order to survive (Mackie et al 1998).

Within the FPNG study area, of the deer that did display migratory behavior, mean migration distances (13.1 km) were greater than those reported in the Meade-Pennington study area (7.4 km) as well as distances reported in central South Dakota (4.5 km; Grassel 2000), and on the prairies of eastern Montana (5.9 km; Wood et al. 1989). However, reported mean migration distances in other studies were greater. Griffin et al. (2005) recorded a mean migration distance of 16 km between seasonal ranges for female mule deer in the southern Black Hills of South Dakota. In northwest Colorado, Garrott et al. (1987) noted mean migration distances were 27 and 43 km for two different study areas. Mean migration distance of 40 km was recorded by Loft et al. (1989) in California. Thomas and Irby (1990) in southeastern Idaho detected average distances of 56 km for females. Likewise, Brown (1992) documented mean distances of 19.9 km for female mule deer in southeastern Idaho. Nicholson (1995) found that average migration distances varied for California mule deer that resided at different elevation levels and documented mule deer that resided below 1500 m elevation migrated an average of

12.6 km (range 8.6 to 19.8 km), and deer that resided above 1500 m in elevation migrated an average of 8.1 km (range 4.4 to 11.3 km). Carrel et al. (1999) studied mule deer in Utah and Arizona and noted average migration distances of 50.9 km and 22.6 km, respectively.

Median spring departure dates for migratory deer in the FPNG study area ranged from 7 April to 17 April over 3 years, and was similar to dates (10 April, and 29 March) documented by Grassel (2000) in central South Dakota, and 18 April in the Meade-Pennington study area. Likewise, Garrott et al. (1987) noted spring migration occurred from April to mid-June in northwest Colorado. In Montana, Wood et al. (1989) stated that spring migrations occurred in late-March to early April. Thomas and Irby (1990) reported variation existed among years in southeastern Idaho, and generally occurred between March-May. Kucera (1992) reported that the median spring departure date in California was 21 April. Nicholson (1995) reported mean dates of 10 April, 29 April, and 1 May over a 3 year period in California. Carrel et al. (1999) noted spring departure in Arizona occurred in late March with completion of migration by mid-May. However, later dates were reported by Griffin et al. (2005), indicating spring migration in the southern Black Hills of South Dakota occurred between mid-May to late-May. As previously stated, we speculate variation in precipitation and temperature influenced timing of spring migrations and deer likely migrated within the FPNG study area when spring green-up occurred.

Median fall departure dates varied in the FPNG study area over the two fall migrational periods documented; however, sample size was a limiting factor. Dates from summer to winter home ranges was 19 January (n=16) ranging from 2 December to 16 February in 2010-2011, and 18 October (n=5) ranging from 4 August to 29 December in 2011-2012. Timing of migrational movements in 2010-11 and 2011-2012 were significantly different. Movements to winter range

in 2011-2012 were similar to those reported in Colorado, with migrations starting in early-October with most deer arriving on winter range by early November (Garrott et al. 1987). Grassel (2000) in central South Dakota noted mean fall migration dates of 3 October, 30 September, and 11 October, respectively. Griffin et al. (2005) indicated most deer occupied winter ranges by the end of November which was similar to other research conducted across the western states (Thomas and Irby 1990, Kucera 1992, Carrel et al. 1999). Wood et al. (1989) found movements occurred between mid-October and late December in Montana. However, movements to winter range in the FPNG study area during 2010-2011 (19 January) appeared to be later than most research documented in other western states and also the Meade-Pennington study area (3 December).

Within the FPNG study area, 37.2% (*n*=43) of the available radio-collared deer displayed fall migratory behavior in 2010-2011 compared to 13.2% (n=38) in 2011-2012. WSI for the winter of 2010-2011 (391.7) was significantly higher than 2011-2012 (129.1). The majority of deer that demonstrated migration in 2010-2011 were conditional and did not migrate annually. The cause and timing of the migration was likely initiated by the above average snowfall that occurred in the FPNG area. A significant snowfall event occurred on 1 January 2011 and shortly thereafter 44% (7/16) of the migratory deer migrated (Figure 6). Another migration pulse occurred during the early part of February, which during this time snow depth exceeded 34 cm for >30 days (Figure 6). We speculate depleted forage resources forced deer to seek out new areas that satisfied life requirements. Furthermore, no variations in crop harvest completion dates existed for corn, sorghum and sunflowers in 2010 and 2011. On 1 November 2010, 81% corn, 95% sorghum and 64% of the sunflowers were harvested compared to 1 November 2011 when 85% corn, 88% sorghum and 56% of the sunflowers were harvested across the state (South

Dakota Agriculture Statistics Service 2013). This further supports our theory that deer likely demonstrated later migration dates (19 January) in 2010-2011 because of the severe winter weather that occurred during this period.

Within the FPNG study area, mean annual 95% home range size of 2,486 ha was similar to other studies conducted in the west. However, variation existed throughout the literature depending on geographical location and habitat present. Eberhardt et al. (1984) noted larger annual home range sizes of female mule deer (3,780 ha) in a sagebrush steppe region in south central Washington. Rautenstrauch and Krausman (1989) also documented larger annual home ranges of 12,100 ha in desert mule deer in Texas. Contrary, home range size of resident deer on the FPNG area were larger than those documented in the Meade-Pennington study area (1,811 ha) characterized by rugged coniferous river breaks. Likewise, annual ranges within the FPNG area were larger than resident females in Texas (284 ha; Dickinson and Garner 1980), Montana (520 ha; Hamlin and Mackie 1989: 630 ha; Wood et al. 1989) and in California (559 ha; Nicholson 1995). Mackie et al. (1998) noted that the first and most fundamental strategy a deer can use in exploiting its local environment is yearlong residency or use of indistinct seasonal ranges. Deer used single yearlong home ranges where the basic requirements of maintenance and reproduction could be satisfied within one local area and microsites important for seasonal requirements were dispersed throughout the area.

Average summer 95% home range size (2,016 ha) for female mule deer that displayed migratory behavior in the FPNG study area was slightly larger than average summer home range size for migratory female mule deer (1,770 ha) in the Meade-Pennington study area; however, average summer home range size in the Meade-Pennington study area was derived using locations over the 3-year period where as the FPNG summer home range size were calculated on

an annual basis; thus, no statistical test was performed. Summer ranges in the FPNG study area were much larger than those reported in Montana (140-640 ha; Pac et al. 1988: 208-288 ha; Wood et al. 1989: 554 ha Nicholson 1995), California (40-200 ha; Loft et al. 1989), Idaho (891-1216 ha; Milner and Unsworth 1996), South Dakota (624 ha; Grassel 2000), California (664 ha; Kie et al. 2002), and 354 ha in the southern Black Hills of South Dakota (Griffin et al. 2005).

In winter, 95% kernel home range size in 2010-11 and 2011-12 averaged 1,772 ha and 2,293 ha, respectively. Average winter home ranges on FPNG study area were larger than home ranges found in other studies. Mule deer winter home ranges were reported in Montana (340-600 ha; Pac et al. 1988: 232-341 ha; Wood et al. 1989), California (1,357 ha; Nicholson 1995: 1,138 ha; Kie et al. 2002), in central South Dakota (431 ha; Grassel 2000), and in the Southern Black Hills of South Dakota (511 ha; Griffin et al. 2005). We speculate that winter ranges were larger in FPNG study area due to the juxtaposition of agricultural lands that were utilized in the winter periods. Likewise, suitable thermal cover may have been a limiting factor and deer may have been forced to move longer distances in order to find the necessary cover to satisfy life requirements. Snow depth has been reported as a contributing factor influencing white-tailed home range sizes within eastern South Dakota. Robling (2011) noted as snow depth increased deer mobility decreased, forcing deer to occupy smaller areas. We speculate snow depth in the FPNG study area did not negatively influence mobility because it rarely exceeded 35 cm.

Mackie et al. (1998) stated that the largest and most variable home range sizes occurred among mule deer and white-tailed deer in prairie-badlands and prairie-agricultural environments which defines habitat characteristics in the FPNG study area. When resource requirements cannot be met in one local area, specialized use of home ranges begin to develop. Furthermore, environments lacking resources to sustain deer are largely unused although deer traverse these

areas during movement to other habitats (Mackie et al. 1998). Factors directly correlated to home range size were not quantified; however, we speculate that large home ranges in the FPNG study area may be related to the juxtaposition of agricultural lands and native grasslands in the area along with other possible environmental covariates including but not limited to; livestock grazing, predator densities, precipitation and human disturbance (e.g., hunting).

Survival

Meade-Pennington Counties

Annual survival rates for female mule deer in the Meade-Pennington study area averaged 83% (range 71%-90%) during 2010-2012, and were similar to annual survival rates documented in Colorado (67%; White and Bartman 1983), Montana (75%; Wood et al. 1989), Utah and Arizona (75%; Carrel et al. 1999) Colorado, Idaho, and Montana (85%; Unsworth et al. 1999b), south central South Dakota (83%- 90%; Grassel 2000) the southern Black Hills (77%; Griffin et al. 2005), southwest Idaho (81.2%; Bishop et al. 2005) and north-central New Mexico (63%-91%; Bender et al. 2006).

Within the Meade-Pennington study area, annual female survival varied significantly between years (2010, 90%; 2011, 71%: 2012, 90%; $p<0.05$). In 2011 (n=40), 9 out of the 12 female mortalities (75%) documented occurred between 1 February – 30 April; thus, an over-winter mortality rate of 22.5% (Figure 7). The WSI for 2010/11 was 239.7 which greatly exceeded values quantified for 2009/10, 2011/12 and 2012/13 (132, 70.9 and 107.4, respectively; Figure 7). We suspect adult female survival in 2011 was greatly influenced by severe winter conditions potentially leading to increased predation and/or malnutrition. These results were similar to Bishop et al. (2005) where severe winter conditions initiated malnutrition, causing lower overall survival rates for adult female and fawn mule deer. This demonstrates over-winter

mortality may have more of an additive affect in the Meade-Pennington study area and managers must keep this into consideration during years of severe winters.

We documented three main causes of mortality in the Meade-Pennington study area on female mule deer as hunting (23%), natural mortality (probable predation; 10%), and unknown mortality (67%) (Figure 3). Wood et al. (1989) found that hunting was the main cause of death among mule deer females in Montana, and other causes such as predation and malnutrition contributed very little to overall mortality. Carrel et al. (1999) reported that 45% of investigated deer deaths were from unknown causes, 6.5% from predators other than mountain lions, 13% from vehicle collisions, and only 9.7% was due to legal hunting. Grassel (2000) found no hunting mortality on female mule deer in south central South Dakota, and natural mortality was the primary cause of mortality. Within similar habitats in Montana, Mackie et al. (1998) noted that although coyote predation on adult females was low, it was the major known natural mortality factor and the second leading cause of death. We experienced a high amount of unknown mortality due to the infrequent monitoring of radio-collared deer in this study area. We speculate predation was a proximal factor in some cases when cause of death could not be determined along with malnutrition during periods of extreme winter weather.

The annual survival rates for male mule deer in Meade and Pennington counties in west central South Dakota during 2010 (56%) and 2011 (60%) were higher than rates found in Montana (30-48%; Wood et al. 1989) and the Black Hills of South Dakota (23%; Griffin et al. 2005). Overall survival rates were similar to documented rates along the Utah and Arizona border (51%; Carrel et al. 1999), and for black tailed deer in Washington (50%; McCorquodale 1999, 50%-52%; Bender et al. 2004). Pac and White (2007) documented annual rates of 52% and 57% on two different study sites in south central Montana.

Hunting mortality (57%) was the main cause of mortality of adult male mule deer (*n*=7) that were radio-collared in our study (Figure 4). Harvest mortality among mule deer males accounted for the majority of mortality in other studies. Carpenter et al. (1979) noted that harvest accounted for 69.3% of the adult male mortality in Colorado. In Montana, Pac et al. (1988) documented that hunting was the major known cause of mortality among male mule deer with 85.7% known deaths from hunting. Wood et al. (1989) noted that hunting was the only cause of death identified among marked adult male mule deer in Montana. Harvest mortality comprised 64% of male mule deer mortality in the western Great Basin of California (Bleich and Taylor 1998). Carrel et al. (1999) reported a lower hunting mortality on mule deer bucks of 37.5%, and Bender et al. (2004) reported that harvest mortality was the primary mortality for male black-tailed deer in Washington, accounting for 47-67% of all mortality. All radio-collared mule deer males in the southern Black Hills of South Dakota, (Griffin et al. 2005), and in south central South Dakota (Grassel 2000) died from hunter harvest. Due to limited sample size (*n*=7) within the Meade-Pennington study area, further research is needed to formulate more reliable survival and hunter harvest mortality rates for male mule deer occupying the prairie landscapes of South Dakota.

FPNG

Annual survival rates for female mule deer in the FPNG study area of central South Dakota during 2010-2012 averaged 77.8% (range 76%-78%) and were slightly lower than what was documented in the Meade-Pennington study area (83%; range 71%-90%), Colorado, Idaho, and Montana (85%; Unsworth et al. 1999b), and south central South Dakota (83%- 90%; Grassel 2000). Survival was, however, similar to annual survival rates documented in Colorado (67%; White and Bartman 1983), Montana (75%; Wood et al. 1989), Utah and Arizona border

(75%; Carrel et al. 1999), the southern Black Hills (77%; Griffin et al. 2005), southwest Idaho (81.2%; Bishop et al. 2005), and north-central New Mexico (63%-91%; Bender et al. 2006).

Four causes of mortality were documented for female mule deer in the FPNG study area and were hunting (33%), natural mortality (30%), vehicle collisions (7%), and unknown mortality (30%), (Figure 5). Hunting harvest rates were 10% higher compared to the Meade-Pennington study area even though female harvest densities for the units encompassing both study areas were not significantly different. Within the Meade-Pennington study area, female harvest densities were 0.07, 0.07 and 0.05 females harvested/km^2 in 2010, 2011 and 2012, respectively. Likewise, female harvest densities in the FPNG study area were 0.08, 0.06, and 0.04 females harvested/km^2 in 2010, 2011 and 2012, respectively. However, the amount of public land within the two study areas was significantly different. Within the Meade-Pennington study area approximately 17% was open to public hunting compared to 32% open to public hunting in the FPNG study area; thus deer in the FPNG study area may have been more susceptible to hunting mortality because of the amount of public lands; thus, increasing hunter harvest rate. Hunter harvest rates were also higher in the FPNG area compared to previously documented rates in central South Dakota where Grassel (2000) found no hunting harvest mortality on female mule deer and noted that natural mortality was the primary cause of mortality. Similar results were documented by Carrel et al. (1999), where only 9.7% of documented mortality resulted from legal hunting. However, similar to the FPNG study area, Wood et al. (1989) documented hunting harvest mortality was the main cause of death among mule deer females in Montana.

We were able to acquire more frequent locations, and had better access to the FPNG study area compared to the Meade-Pennington study area. This allowed us to better quantify

causes of mortality on the FPNG study area, and thus we were able to document more natural mortality, and less unknown mortality. The majority of natural mortality was presumed to be coyote predation, although the ultimate cause of mortality was difficult to confirm in most cases. Mackie et al. (1998) found that although coyote predation on adult females was low, it was the major known natural mortality factor and the second leading cause of death overall. Predation was also suspected to be at least the proximal factor in some cases of unknown cause. Furthermore, vehicle collision mortality documented in the FPNG study area of 7% was similar to vehicle collision mortality (13%) in Utah and Arizona (Carrel et al. 1999).

Similar to the Meade-Pennington study area, correlation existed between the WSI and over-winter mortality rates in the FPNG study area. In 2011 (n=45), 7 out of the 11 female mortalities (64%) documented occurred between 1 February – 30 April; thus, an over-winter mortality rate of 16% (Figure 8). The WSI for 2010/11 was 391.7 which greatly exceeded values quantified for 2009/10, 2011/12 and 2012/13 (257.9, 129.1 and 250.4, respectively; Figure 8). We suspect adult female survival in 2011 was greatly influenced by severe winter conditions potentially leading to increased predation and/or malnutrition. However, no variation in annual survival existed between years (2010, 77%: 2011, 76% and 2012, 78%), therefore indicating some adult female mule deer do not survive each year, regardless of winter severity or other causes of mortality. Thus, overwinter mortality, in this case, may have been more compensatory. Similarly, Bishop et al. (2005) stated that coyote predation in Colorado was likely compensatory; thus, supporting this theory.

MANAGEMENT IMPLICATIONS

Sightability

Results obtained in the Meade-Pennington County study area demonstrated that fixed-wing aerial surveys are not a feasible method in quantifying deer population estimates in areas with extreme coniferous canopy cover associated with rugged terrain. As a result, alternative methods should be used in estimating mule deer population size in areas that are characterized by coniferous river breaks. One alternative method would be to monitor survival rates for each segment of the population (adult females, adult males and fawns) to formulate an annual rate of change and population estimate through intensive modeling techniques. When considering the standard error of a survival estimate; White and Bartmann (1997) suggest that approximately 50 individuals of the target population must be marked to achieve survival estimates with reasonable precision. As a result, we recommend radio-collaring large samples (i.e., ≥ 50) of adult females, males and fawn mule deer within each data analysis unit of interest. Annual survival rates, along with cause-specific mortality would be quantified separately for males, females and fawns and these rates would then be used for modeling purposes to formulate population estimates.

Another alternative method potentially could be the development of a mule deer sightability model using a helicopter. Mule deer surveys using helicopters have been utilized extensively in most western states including Arizona, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, and Washington. Currently, Texas, New Mexico, and Idaho formulate mule deer estimates using sightability models, while the remaining states use helicopter survey techniques to collect data on age class (fawn vs. adult), group size (abundance) and sex (deVos et al. 2003). These data are then used as inputs for a computer modeling program POP II (Fossil

Creek Software, Fort Collins, CO) to estimate population characteristics and make harvest decisions.

Results obtained in the FPNG study area indicated that fixed-wing aerial surveys for mule deer are a feasible method when mule deer are occupying prairie habitats that are characterized by open grasslands. Because sightability rates increase significantly with the presence of snow, we recommend utilizing the snow model exclusively. This will provide managers with more precise and accurate population estimates, along with narrower variance ranges. This model can assist game managers in determining more accurate population estimates by incorporating correction factors for groups of deer observed during aerial surveys in grassland dominated landscapes throughout similar habitat types in central and western South Dakota.

However, all deer management units in western South Dakota contain some habitats exhibiting extreme terrain ruggedness and/or dense canopy cover. As demonstrated in the Meade-Pennington study area, deer in these habitats cannot be successfully estimated using fixed-wing aerial surveys. The proportion of the deer population inhabiting these areas during winter aerial surveys would remain unknown; therefore surveying only open habitats will result in incomplete estimates of total deer populations within each management unit. If aerial estimates are to be used by managers to evaluate deer densities in management units, then fixed-winged surveys must be combined with helicopter surveys. Sightability models using helicopters will therefore need to be developed in order to correctly utilize aerial surveys to estimate mule deer populations in South Dakota.

Furthermore, regardless of model selection, in order to reduce bias, aerial surveying procedures must rigorously follow sampling protocols established during model development. When utilizing the snow model, surveys can only be flown when 100% snow cover is present

and deer are in large herds. All survey guidelines (e.g., height, speed, transect width) must be followed consistently with the protocol developed during winter and spring sightability trials.

Home Range and Movements

Understanding timing, distance and potential causes of mule deer movements within central and western South Dakota will assist managers in deciding how movement strategies and timing of these movements should be incorporated into population modeling, season recommendations, and if deer units should be based on physiographic regions rather than county lines. This study revealed that the majority of mule deer occupying prairie and river break habitats are considered resident deer, and occupy large annual home ranges. However, some individuals displayed mixed movement strategies and were residents one year and conditional migrators the next. Justification as to why mixed movement strategies were documented could not be determined; however, we speculate weather conditions, crop rotations, human disturbance, and predator densities may have been contributing factors. Factors such as these potentially could influence migration/movements; thus, affecting harvest availability and should be considered throughout the season setting process.

Within the Meade-Pennington study area, mule deer occupied the same management unit during all seasons and rarely crossed management unit boundaries. However, this was contrary to the FPNG study area where some individuals occupied up to four different management units annually. As a result, unit population estimates in open prairie habitats have the potential to fluctuate spatially through time. Likewise, because of the large home range sizes and mixed movement strategies documented in this study, mule deer populations in close proximity to unit boundaries have a significant chance of crossing unit boundaries, especially when these unit boundaries are political, such as county lines. In the Meade-Pennington study area, it appeared

physiological boundaries (i.e., Cheyenne River) may have had an effect on the occurrence of deer crossing management unit boundaries. Thus, managers need to keep this into consideration when changing management unit boundaries, allocating tag numbers and estimating population sizes.

To mitigate this movement effect on population estimates we suggest consolidating management units in data analysis units (DAU). This strategy would consolidate 3-5 management units that include similar habitat types, weather conditions and harvest strategies and population estimates would then be quantified for the total DAU. Furthermore, we do not suggest consolidating management units into larger hunting units because hunter distribution issues would certainly arise, especially on public lands and private lands leased for public hunting. Smaller management units allow wildlife managers the opportunity to control hunter distribution, target harvest where needed, and prevent the over-utilization of public areas.

Information regarding home range size will assist managers with better understanding the mechanistic relationship between the size of an occupied home range and the quality and quantity of suitable habitats available. Animals likely select and use resources that satisfy life requirements and if these suitable resources are not available, movements and home range size may be affected. When animals cannot substitute resource quantity for more quality and vice versa, animal use changes as population density changes. To predict these changes, we must thoroughly understand the relationship that influences animal distribution and behavior. Evaluating the quantity and quality of wildlife habitat is an important component to land management because resource use is dependent on the habitat that is available. As a result, a thorough analysis incorporating resource selection of mule deer occupying western South Dakota needs to be conducted. This analysis would answer questions pertaining to how habitat

juxtaposition, temporal changes to habitat, and overall habitat availability affect home range sizes and movements. It would also be advantageous to quantify the potential effects of livestock grazing on mule deer use and selection.

Survival

Survival estimates are a critical component of deer management and are needed for modeling purposes to estimate population size, potential harvest quotas and to formulate an annual rate of change (λ). Vital rates for mule deer obtained through this study were the first in over a decade and the continuation of survival monitoring of deer herds across the state is imperative in order to make justifiable scientific management decisions. Because annual survival of mule deer can vary significantly in response to a variety of different covariates (e.g., environmental conditions, harvest strategies etc.), managers need long term trend data in order to make inferences about population growth and decline. Furthermore, detailed information regarding neonate survival and recruitment rates are also needed for modeling purposes and continued effort to quantify these vital rates are very important. Without accurate and up-to-date recruitment and survival statistics, inaccuracies and variability across years will continue to be a concern for managers. Thus, we strongly recommend radio-collaring large samples ($\geq$50) of adult female and fawn mule deer within each designated DAU of interest, to obtain much needed vital rate data across the majority of South Dakota's mule deer range.

When considering male mule deer survival, high hunter harvest rates should be a concern. Although we had a small sample of marked males in the Meade-Pennington study area, we discovered that hunting accounted for 57% of overall mortality. Further research is needed on survival and cause-specific mortality of mule deer males in the prairie regions of South Dakota. As a result, we suggest radio-collaring a significant sample of male mule deer ($\geq$50)

within each predefined DAU of interest to monitor and determine annual survival rates, hunter harvest rates, and other mortality factors. These data would assist in managing this segment of the population and immensely improve modeling inputs.

Hunter harvest mortality is a leading contributor to overall mule deer mortality; however, the lack of exact knowledge on other causes of mortality is a concern. We noted 67%, and 30% unknown mortality causes in the Meade-Pennington and FPNG study areas, respectively. More research may be needed on cause-specific mortality on all sex and age classes of mule deer in South Dakota to determine the potential for alternative management strategies. An example of this would be predator control in areas where high predator populations have a known effect on mule deer survival. Harrington and Conover (2007) suggest that coyote control for livestock protection may increase mule deer densities; however, Brown and Conover (2011) documented mule deer productivity and abundance were not correlated with either the number of coyotes removed or the removal effort. Thus, further research needs to be conducted within South Dakota pertaining to the removal of coyotes and how that may or may not affect mule deer recruitment and/or abundance, before a large-scale removal program was ever implemented.

Furthermore, annual weather conditions are another factor that must be considered when managing mule deer populations. Drought conditions, especially in arid climates of the western United States, have been known to affect overall survival and recruitment of mule deer populations. Over-winter forage conditions are negatively impacted from summer drought, potentially causing increased mortality rates due to increased predation and mal-nutrition. Likewise, severe winter weather may also affect over-winter survival and this was well documented in both the Meade-Pennington and FPNG study sites where excessive snow fall combined with cold temperatures affected mule deer survival. Winter severity models in South

Dakota may prove advantageous to managers to assist in modeling and projecting mule deer populations. We recommend the continuation of investigating the correlation between severe winter weather and mule deer survival and recruitment. Likewise, the correlation between summer drought conditions and mule deer survival needs further investigation.

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TABLES

Table 1. Deer sightability results by independent variable from spring aerial survey observations (*n*=46) from Meade and Pennington Counties in western South Dakota, 2010-2012.

Variable		No. of groups		Visibility
		Missed	Seen	
Behavior				
	Active	9	3	0.25
	Standing	24	5	0.17
	Bedded	3	2	0.40
% Canopy Cover				
	0	5	3	0.38
	1-24	5	3	0.38
	25-49	16	4	0.20
	50-74	4	0	0.00
	75-100	6	0	0.00
Group Size				
	1-3	11	3	0.21
	3-4	11	0	0.00
	5-6	9	4	0.31
	7-8	3	1	0.20
	9+	2	2	0.50
Habitat Type				
	Deciduous Trees	6	0	0.00
	Coniferous Trees	23	7	0.23
	Tall Grass	2	0	0.00
	Open	5	3	0.38
Topography				
	Flat	4	1	0.20
	Draw High	12	5	0.29
	Draw Medium	12	3	0.20
	Draw Low	8	1	0.11

Table 2. Model covariates, number of parameters (K), Akaike's Information Criterion adjusted for small sample size (AIC_c), differences in AIC_c, lowest AIC_c value (ΔAIC_c), and Akaike model weights (w_i) for the spring model set evaluated for mule deer sightability in Meade and Pennington Counties in western South Dakota, 2010-2012.

Model covariates	K	AIC_c	ΔAIC_c	w_i
Canopy Cover	2	47.195	0.000	0.247
Canopy Cover + Group Size	3	48.332	1.138	0.140
Canopy Cover + Habitat	3	48.948	1.754	0.103
Canopy Cover + Habitat+ Group Size	4	48.951	1.757	0.103
Canopy Cover + Activity	3	49.203	2.009	0.090
Canopy Cover + Topography	3	49.273	2.079	0.087
Canopy Cover + Activity+ Group Size	4	50.408	3.214	0.049
Canopy Cover + Topography + Group Size	4	50.442	3.248	0.049
Canopy Cover + Habitat + Activity	4	51.004	3.810	0.037
Canopy Cover + Habitat + Activity + Group Size	5	51.086	3.891	0.035
Canopy Cover + Activity + Topography	4	51.295	4.101	0.032
Canopy Cover + Activity + Topography + Group Size	5	52.539	5.344	0.017
Canopy Cover + Activity + Topography + Group Size +	6	53.254	6.060	0.012

Table 3. Results from stepwise regression model from spring aerial survey observations (n=46) from Meade and Pennington Counties in western South Dakota, 2010-2012.

Variable	Parameter estimate	SE	t-ratio	P
Intercept	-0.126	0.607	-0.208	**0.835**
Canopy Cover	-0.748	0.364	-2.054	0.040

Table 4. Deer sightability results by independent variable from winter aerial survey observations (n=80) from Meade and Pennington Counties in western South Dakota, 2010-2011.

Variable		No. of groups		Visibility
		Missed	Seen	
Behavior				
	Active	19	7	0.27
	Standing	19	26	0.58
	Bedded	8	1	0.11
% Canopy Cover				
	0	0	11	1.00
	1-24	9	16	0.64
	25-49	16	6	0.27
	50-74	14	1	0.07
	75-100	7	0	0.00
Group Size				
	1-3	13	4	0.24
	4-6	17	8	0.32
	7-10	14	6	0.30
	11-13	2	5	0.71
	14+	0	11	1.00
Habitat Type				
	Trees	31	4	0.11
	Open	15	30	0.67
Topography				
	Flat	2	17	0.90
	Draw High	12	7	0.37
	Draw Medium	26	9	0.26
	Draw Low	6	1	0.14

Table 5. Model covariates, number of parameters (K), Akaike's Information Criterion adjusted for small sample size (AIC_c), differences in AIC_c, lowest AIC_c value (ΔAIC_c), and Akaike model weights (w_i) for the 100% snow cover model set evaluated for mule deer sightability in Meade and Pennington Counties in western South Dakota, 2010-2012.

Model covariates	K	AIC_c	ΔAIC_c	w_i
Canopy Cover + Group Size	3	68.276	0.000	0.284
Canopy Cover + Topography + Group Size	4	69.359	1.083	0.165
Canopy Cover + Habitat+ Group Size	4	69.915	1.639	0.125
Canopy Cover + Activity+ Group Size	4	70.370	2.094	0.100
Canopy Cover + Topography	3	71.000	2.724	0.073
Canopy Cover + Activity + Topography + Group Size	5	71.493	3.217	0.057
Canopy Cover	2	71.864	3.587	0.047
Canopy Cover + Habitat + Activity+ Group Size	5	72.052	3.776	0.043
Canopy Cover + Habitat	3	72.717	4.441	0.031
Canopy Cover + Activity + Topography	4	73.108	4.832	0.025
Canopy Cover + Activity + Topography + Group Size + Habitat	6	73.240	4.964	0.024
Canopy Cover + Activity	3	73.944	5.668	0.017
Canopy Cover + Habitat + Activity	4	74.820	6.544	0.011

Table 6. Results from stepwise regression model from winter aerial survey observations with 100% snow cover (n=80) from Meade and Pennington Counties in western South Dakota, 2010-2011.

Variable	Parameter estimate	SE	t-ratio	P
Intercept	1.733	0.927	1.870	**0.062**
Canopy Cover	-1.680	0.450	-3.731	0.000
Group Size	0.072	0.066	1.094	**0.274**

Table 7. Deer sightability results by independent variable from spring aerial survey observations (n=253) from Fort Pierre National Grasslands in central South Dakota, 2010-2012.

Variable		No. of groups		Visibility
		Missed	Seen	
Behavior				
	Active	7	27	0.79
	Standing	43	114	0.73
	Bedded	37	26	0.41
% Visual Obstruction				
	0	69	157	0.70
	1-24	1	3	0.75
	25-49	8	4	0.33
	50-74	5	2	0.29
	75-100	4	1	0.20
Group Size				
	1-3	26	26	0.50
	4-6	25	41	0.62
	7-9	22	31	0.59
	10-14	7	25	0.78
	15+	7	44	0.86
Habitat Type				
	Deciduous Trees	8	6	0.43
	Tall Grass	2	0	0.00
	Open	77	161	0.68
Topography				
	Flat	21	82	0.80
	Shallow Draw	46	65	0.59
	Medium Draw	19	20	0.51
	Deep Draw	1	0	0.00

Table 8. Model covariates, number of parameters (K), Akaike's Information Criterion adjusted for small sample size (AIC_c), differences in AIC_c, lowest AIC_c value (ΔAIC_c), and Akaike model weights (w_i) for the spring model set evaluated for mule deer sightability in the Fort Pierre National Grasslands in central South Dakota, 2010-2012.

Model covariates	K	AIC_c	ΔAIC_c	w_i
Group Size + Activity + Topography	4	290.768	0.000	0.902
Group Size + Activity	3	295.924	5.156	0.069
Topography + Activity	3	297.904	7.136	0.025
Topography + Group Size	3	302.048	11.280	0.003
Group Size	2	306.945	16.176	0.000
Activity	3	309.530	18.761	0.000
Topography	2	314.066	23.297	0.000

Table 9. Results from stepwise regression model from spring aerial survey observations (n=253) from Fort Pierre National Grasslands in central South Dakota, 2010-2012.

Variable	Parameter estimate	SE	t-ratio	P
Intercept	2.982	0.764	3.905	0.000
Group Size	0.067	0.241	2.770	0.005
Activity	-0.865	0.245	-3.530	0.000
Topography	-0.568	0.213	-2.665	0.008

Table 10. Deer sightability results by independent variable from winter aerial survey observations with 100% snow cover (*n*=298) from Fort Pierre National Grasslands in central South Dakota, 2010-2012.

Variable		No. of groups		Visibility
		Missed	Seen	
Behavior				
	Active	14	48	0.77
	Standing	19	127	0.87
	Bedded	13	77	0.86
% Visual Obstruction				
	0	36	239	0.87
	1-24	0	0	0.00
	25-49	7	9	0.56
	50-74	3	3	0.50
	75-100	0	1	1.00
Group Size				
	1-3	15	38	0.72
	4-6	10	36	0.78
	7-10	12	28	0.70
	11-16	3	27	0.90
	17+	6	123	0.95
Habitat Type				
	Deciduous Trees	2	1	0.33
	Coniferous Trees	0	4	1.00
	Wetlands	0	1	1.00
	Tall Grass	5	13	0.78
	Open	38	232	0.86
	Developed	1	1	0.50
Topography				
	Flat	11	154	0.93
	Shallow Draw	16	66	0.80
	Medium Draw	19	32	0.63
	Deep Draw	0	0	0

Table 11. Model covariates, number of parameters (K), Akaike's Information Criterion adjusted for small sample size (AIC_c), differences in AIC_c, lowest AIC_c value (ΔAIC_c), and Akaike model weights (w_i) for the 100% snow cover model set evaluated for mule deer sightability in the Fort Pierre National Grasslands in central South Dakota, 2010-2012.

Model covariates	K	AIC_c	ΔAIC_c	w_i
Group size + Topography	3	223.312	0.000	0.577
Group Size + Activity + Topography	4	224.032	0.720	0.403
Group Size + Activity	3	231.822	8.510	0.008
Group size	2	232.411	9.098	0.006
Topography	2	233.421	10.108	0.004
Topography + Activity	3	234.752	11.440	0.002
Activity	2	259.031	35.718	0.000

Table 12. Results from stepwise regression model from winter aerial survey observations with 100% snow cover (n=298) from Fort Pierre National Grasslands in central South Dakota, 2010-2012.

Variable	Parameter estimate	SE	t-ratio	P
Intercept	2.363	0.563	4.200	0.000
Group Size	0.054	0.019	2.857	0.004
Topography	-0.742	0.226	-3.284	0.001

Table 13. Deer sightability results by independent variable from winter aerial survey observations with no snow cover (*n*=94) from Fort Pierre National Grasslands in central South Dakota, 2012.

Variable		No. of groups		Visibility
		Missed	Seen	
Behavior				
	Active	0	4	1.00
	Standing	16	44	0.73
	Bedded	23	7	0.23
% Visual Obstruction				
	0	26	49	0.65
	1-24	1	0	0.00
	25-49	1	4	0.80
	50-74	8	2	0.20
	75-100	3	0	0.00
Group Size				
	1-3	11	5	0.31
	4-6	12	15	0.56
	7-9	12	13	0.52
	10-12	3	7	0.70
	13+	1	15	0.94
Habitat Type				
	Tall Grass	11	8	0.42
	Open	28	47	0.63
Topography				
	Flat	4	20	0.83
	Shallow Draw	15	29	0.66
	Medium Draw	20	6	0.23
	Deep Draw	0	0	0

Table 14. Model covariates, number of parameters (K), Akaike's Information Criterion adjusted for small sample size (AIC_c), differences in AIC_c, lowest AIC_c value (ΔAIC_c), and Akaike model weights (w_i) for the no snow winter model evaluated for mule deer sightability in the Fort Pierre National Grasslands in central South Dakota, 2010-2012.

Model covariates	K	AIC_c	ΔAIC_c	w_i
Group size + Activity + Topography + Visual	5	79.731	0.000	0.643
Group size + Activity + Topography	4	81.915	2.184	0.216
Activity + Topography + Visual Obstruction	4	83.235	3.504	0.112
Activity + Topography	3	85.981	6.250	0.028
Topography + Group size + Visual Obstruction	4	92.547	12.816	0.001
Group size + Activity	3	97.112	17.381	0.000
Group size + Activity + Visual Obstruction	4	98.055	18.324	0.000
Topography + Visual Obstruction	3	98.212	18.481	0.000
Group size + Topography	3	102.820	23.089	0.000
Activity	2	106.571	26.840	0.000
Activity + Visual Obstruction	3	107.466	27.735	0.000
Group size + Visual Obstruction	3	108.568	28.837	0.000
Topography	2	111.160	31.429	0.000
Group Size	2	114.032	34.301	0.000
Visual Obstruction	2	122.315	42.584	0.000

Table 15. Results from stepwise regression model from winter aerial survey observations with no snow cover (n=94) from Fort Pierre National Grasslands in central South Dakota, 2010-2012.

Variable	Parameter estimate	SE	t-ratio	P
Intercept	9.509	2.568	3.703	0.0002
Visual Obstruction	-0.603	0.296	-2.034	0.042
Group Size	0.184	0.086	2.139	0.032
Topography	-2.132	0.572	-3.728	0.0002
Activity	-2.444	0.734	-3.328	0.0009

Table 16. Annual survival rates for radio-collared female mule deer in Meade-Pennington Counties, South Dakota, 2010-2012.

	2010	2011	2012
Number at Risk	39	40	49
Number of Deaths	4	12	5
Number Censored	1	1	1
Survival Rate	0.90	0.71	0.90
SE	0.048	0.071	0.043
95% CI lower	0.757	0.552	0.777
95% CI upper	0.961	0.825	0.957

Table 17. Annual survival rates for radio-collared male mule deer in Meade-Pennington Counties, South Dakota, 2010-2012.

	2010	2011
Number at Risk	9	5
Number of Deaths	4	2
Number Censored	1	0
Survival Rate	0.56	0.60
SE	0.166	0.219
95% CI lower	0.251	0.200
95% CI upper	0.823	0.899

Table 18. Annual survival rates for radio-collared female mule deer in Lyman, Stanley, and Jones Counties (FPNG), South Dakota, 2010-2012.

	2010	2011	2012
Number at Risk	48	46	36
Number of Deaths	11	8	11
Number Censored	2	0	0
Survival Rate	0.77	0.76	0.78
SE	0.061	0.063	0.069
95% CI lower	0.632	0.619	0.615
95% CI upper	0.868	0.863	0.885

Figures

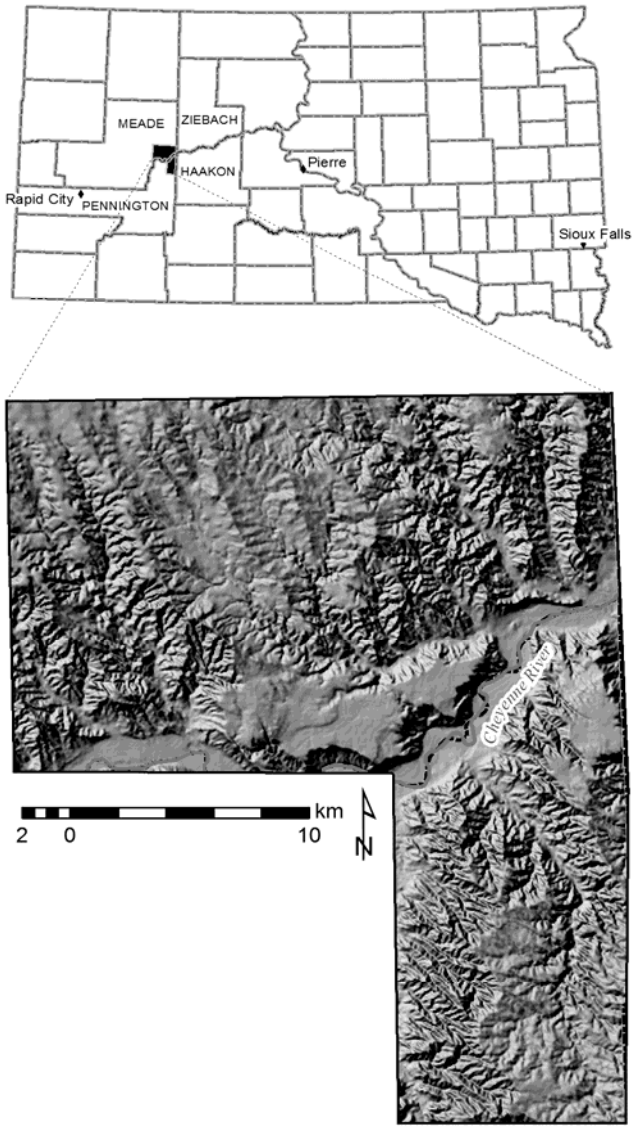

Figure 1. Meade-Pennington Counties study area for mule deer in western South Dakota, 2010-2012.

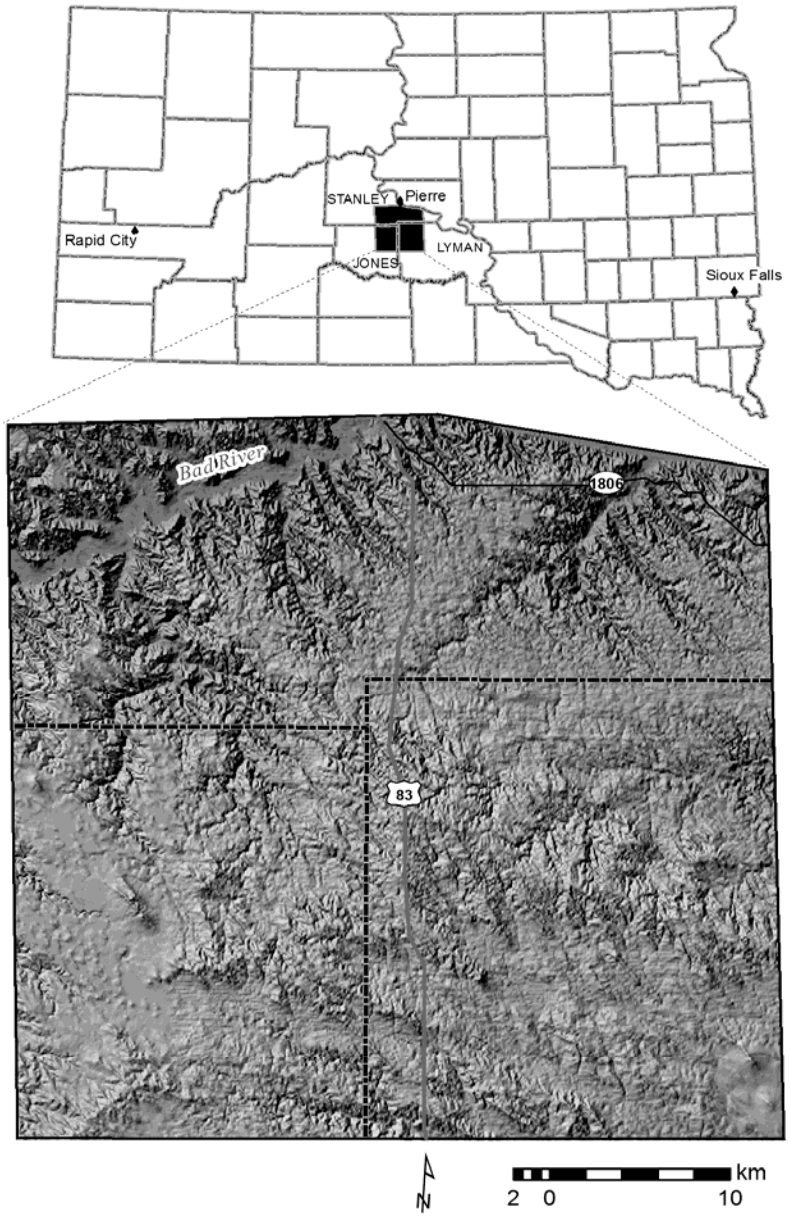

Figure 2. Fort Pierre National Grasslands (FPNG) study area for mule deer in central South Dakota, 2010-2012.

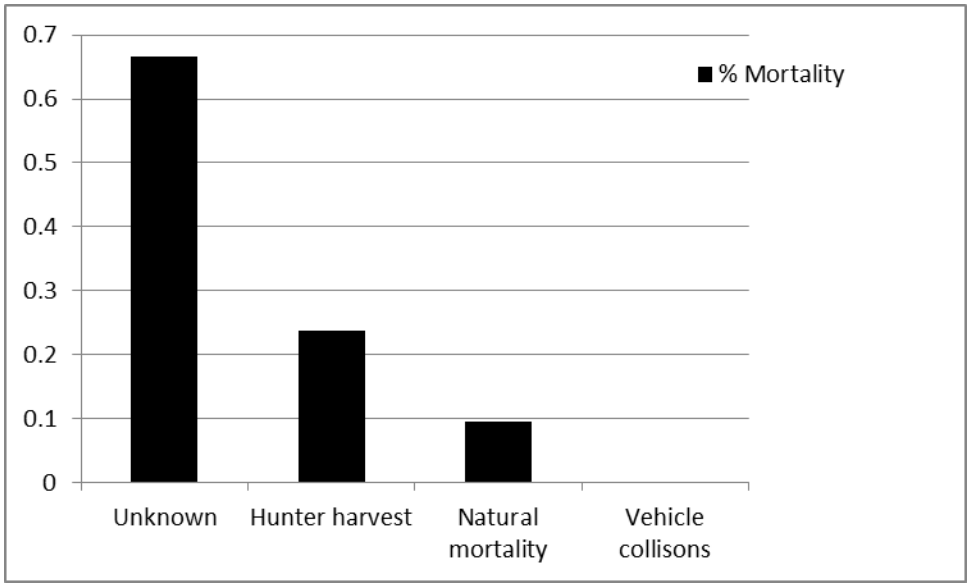

Figure 3. Percent cause-specific mortality (n=21) of radio-collared mule deer females in Meade-Pennington, South Dakota, 2010-2012.

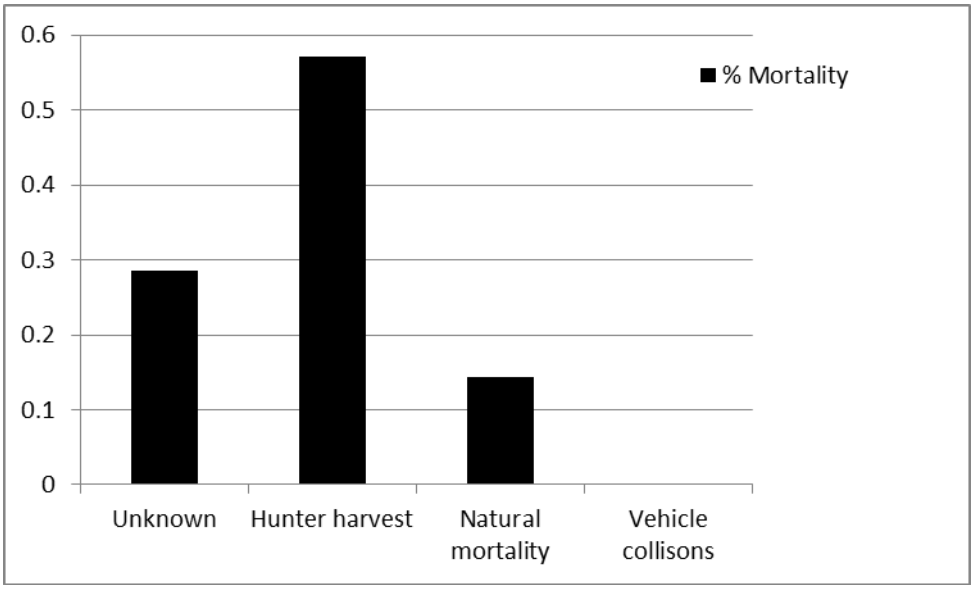

Figure 4. Percent cause-specific mortality (n=7) of radio-collared mule deer males in Meade-Pennington, South Dakota, 2010-2012.

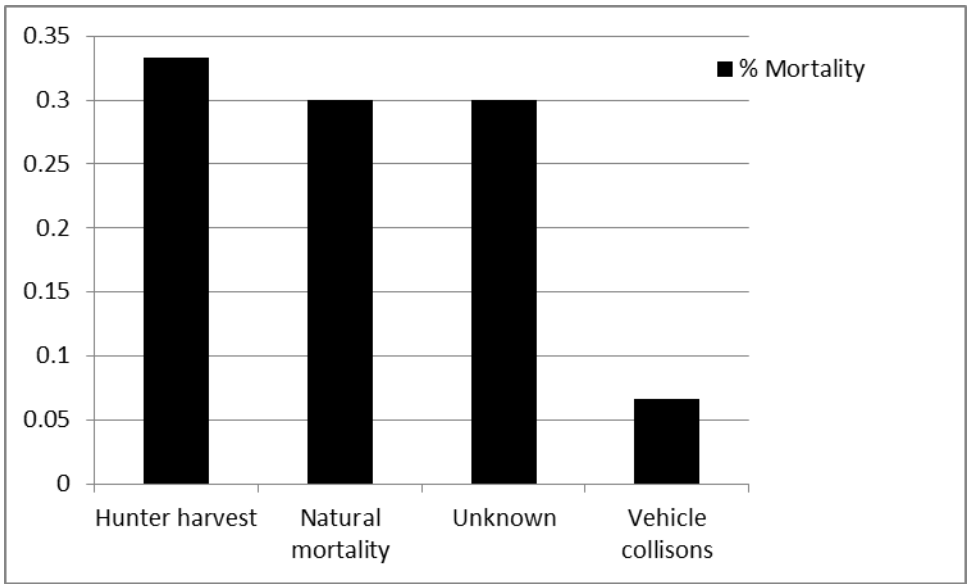

Figure 5. Percent cause-specific mortality (n=30) of radio-collared mule deer females in FPNG, South Dakota, 2010-2012.

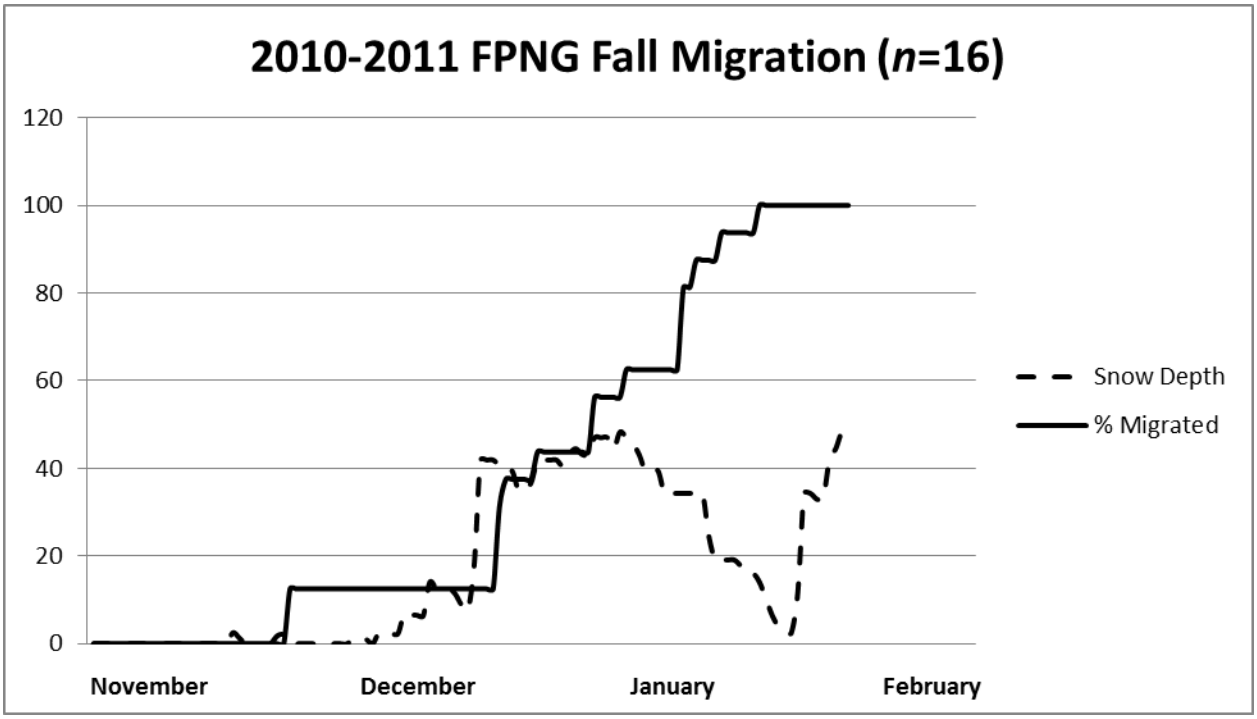

Figure 6. Fall migration for radio-collared mule deer in the FPNG, South Dakota. Two variables compose the Y-axis (i.e., snow depth [cm] and migratory deer [%]).

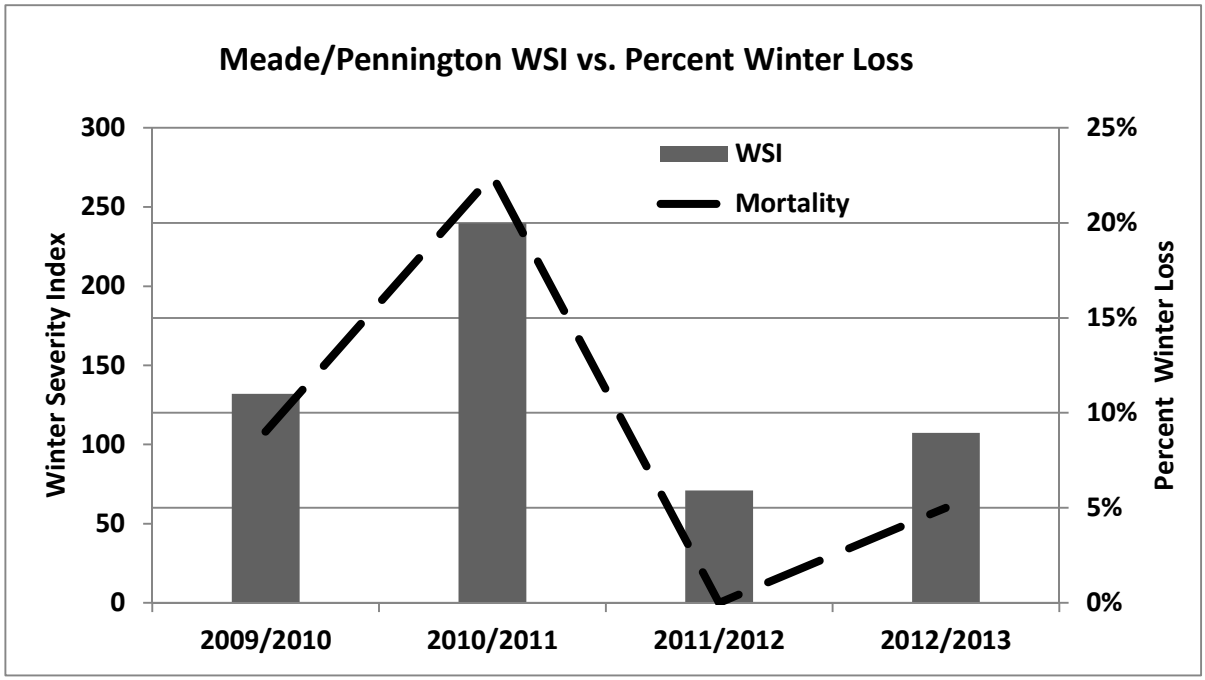

Figure 7. Yearly winter severity index (WSI) versus percent winter loss (i.e., Over-winter mortality; February 1-April 31) of deer for Meade-Pennington, South Dakota, 2009-2013.

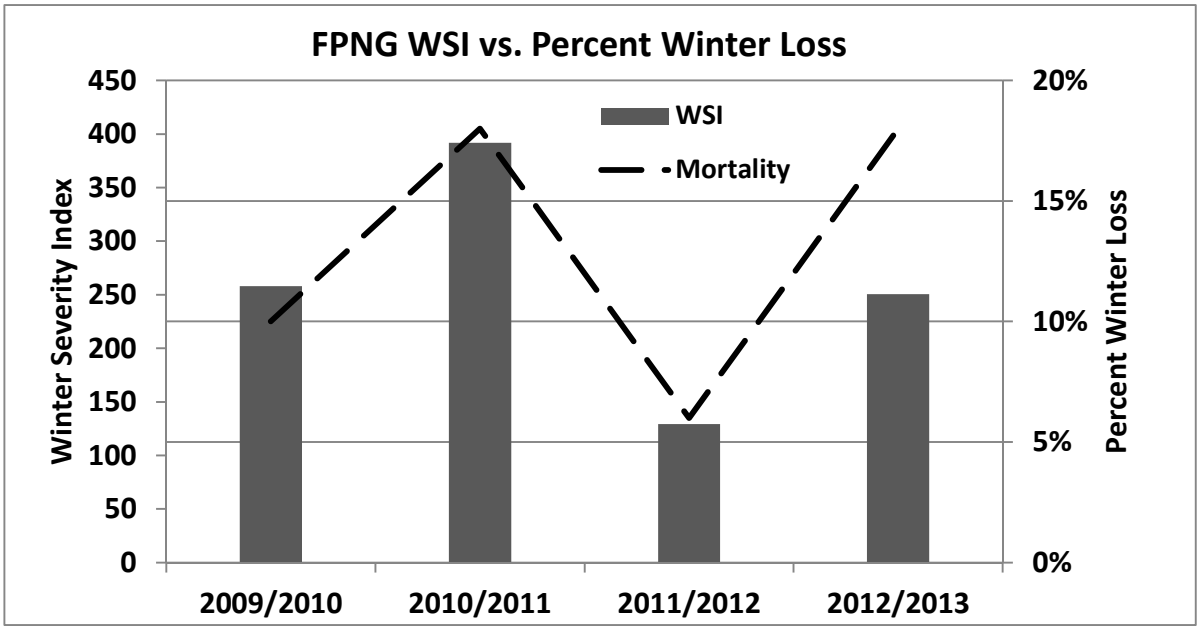

Figure 8. Yearly winter severity index (WSI) versus percent winter loss (i.e., Over-winter mortality; February 1-April 31) of deer for FPNG, South Dakota. 2009- 2013.

APPENDIX

Appendix A. Capture data for mule deer in Meade-Pennington Counties, South Dakota, 2010-2012.

Capture Date	Frequency	Sex	Age	Latitude	Longitude
01/26/2010	151.530	female	adult	44.46452	-102.20933
01/26/2010	151.160	female	adult	44.40260	-102.02663
01/26/2010	151.140	female	adult	44.47927	-102.07535
01/26/2010	151.100	female	adult	44.48042	-102.10517
01/26/2010	151.040	female	adult	44.52032	-102.24457
01/26/2010	151.010	female	adult	44.50045	-102.22872
01/26/2010	150.960	female	adult	44.53028	-102.09393
01/26/2010	150.880	female	adult	44.47025	-102.21573
01/26/2010	150.860	male	adult	44.47202	-102.21080
01/26/2010	150.840	female	adult	44.47370	-102.21263
01/26/2010	150.820	male	adult	44.38863	-102.03672
01/26/2010	150.770	female	adult	44.41745	-102.09083
01/26/2010	150.750	female	adult	44.39222	-102.07893
01/26/2010	150.710	female	adult	44.51270	-102.23562
01/26/2010	150.690	female	adult	44.43505	-102.05353
01/26/2010	150.670	female	adult	44.42017	-102.03242
01/26/2010	150.610	female	adult	44.40942	-102.06208
01/26/2010	150.580	female	adult	44.43150	-102.07590
01/26/2010	150.560	male	adult	44.40405	-102.05192
01/26/2010	150.490	female	adult	44.41917	-102.02665
01/26/2010	150.440	male	adult	44.46588	-102.08815
01/26/2010	150.410	female	adult	44.50112	-102.21647
01/26/2010	150.390	female	adult	44.45225	-102.04413
01/26/2010	150.330	female	adult	44.41402	-102.07055
01/26/2010	150.290	female	adult	44.46603	-102.10952
01/26/2010	150.270	female	adult	44.48418	-102.08713
01/26/2010	150.230	female	adult	44.47743	-102.25585
01/26/2010	150.210	female	adult	44.37678	-102.10835
01/26/2010	150.170	male	adult	44.38077	-102.09625
01/26/2010	150.130	female	adult	44.40303	-102.04555
01/26/2010	150.100	female	adult	44.48663	-102.23207
01/26/2010	150.080	male	adult	44.52028	-102.29170
01/26/2010	150.060	female	adult	44.53362	-102.08310
01/26/2010	150.350	female	adult	44.50256	-102.11816
01/27/2010	151.180	female	adult	44.55347	-102.07865
01/27/2010	151.120	male	adult	44.53672	-102.09552
01/27/2010	151.080	female	adult	44.52318	-102.08228
01/27/2010	151.060	male	adult	44.40603	-102.08955
01/27/2010	150.980	female	adult	44.55547	-102.05583
01/27/2010	150.920	female	adult	44.49047	-102.12672
01/27/2010	150.800	female	adult	44.47638	-102.07800

Appendix A con't. Capture data for mule deer in Meade-Pennington Counties, South Dakota, 2010-2012.

Capture Date	Frequency	Sex	Age	Latitude	Longitude
01/27/2010	150.730	female	adult	44.46382	-102.09730
01/27/2010	150.700	female	adult	44.50063	-102.16718
01/27/2010	150.650	female	adult	44.55808	-102.09907
01/27/2010	150.630	male	adult	44.55105	-102.02140
01/27/2010	150.530	female	adult	44.49422	-102.13380
01/27/2010	150.510	female	adult	44.41243	-102.10452
01/27/2010	150.250	male	adult	44.53308	-102.10978
01/27/2010	150.190	female	adult	44.40603	-102.08955
01/27/2010	150.020	female	adult	44.54635	-102.10703
02/21/2011	150.190	female	adult	44.47347	-102.21333
02/21/2011	150.210	female	adult	44.36900	-102.10108
02/21/2011	150.250	female	adult	44.49928	-102.15025
02/21/2011	150.440	female	adult	44.52993	-102.25840
02/21/2011	150.820	female	adult	44.46730	-102.10927
02/21/2011	150.920	female	adult	44.42747	-102.06620
02/21/2011	151.010	female	adult	44.40235	-102.05303
02/21/2011	151.180	female	adult	44.50913	-102.23035
02/29/2012	150.580	female	adult	44.38946	-102.04192
02/29/2012	150.670	female	adult	44.38389	-102.04200
02/29/2012	150.710	female	adult	44.41412	-102.08566
02/29/2012	150.730	female	adult	44.40102	-102.08386
02/29/2012	150.860	female	adult	44.39721	-102.07576
02/29/2012	151.010	female	adult	44.40247	-102.07178
02/29/2012	151.360	female	adult	44.40056	-102.06435
03/01/2012	150.570	female	adult	44.36176	-102.23727
03/01/2012	150.760	female	adult	44.47768	-102.22149
03/01/2012	151.180	female	adult	44.40111	-102.05775
03/01/2012	151.070	female	adult	44.37894	-102.03732
03/01/2012	150.840	female	adult	44.38939	-102.04163
03/01/2012	151.040	female	adult	44.52232	-102.09487
03/01/2012	150.610	female	adult	44.53900	-102.10133
03/01/2012	150.560	female	adult	44.53320	-102.10336
03/01/2012	150.950	female	adult	44.47588	-102.21095
03/01/2012	151.060	female	adult	44.53500	-102.25657
03/01/2012	151.850	female	adult	44.53144	-102.26093
03/01/2012	151.870	female	adult	44.53535	-102.26473
03/01/2012	151.890	female	adult	44.49406	-102.23899

Appendix B. Capture data for mule deer in Lyman, Stanley, and Jones Counties (FPNG), South Dakota, 2010-2012.

Capture Date	Frequency	Sex	Age	Latitude	Longitude
01/28/2010	150.090	female	adult	44.09923	-100.47560
01/28/2010	150.110	female	adult	44.19278	-100.44042
01/28/2010	150.140	female	adult	44.22245	-100.35246
01/28/2010	150.240	female	adult	44.22065	-100.50111
01/28/2010	150.280	female	adult	44.20886	-100.39629
01/28/2010	150.310	female	adult	44.14861	-100.52517
01/28/2010	150.600	female	adult	44.09616	-100.50638
01/28/2010	150.640	female	adult	44.13805	-100.44265
01/28/2010	150.660	female	adult	44.26393	-100.24099
01/28/2010	150.680	female	adult	44.09611	-100.28536
01/28/2010	150.760	female	adult	44.10658	-100.19311
01/28/2010	150.790	female	adult	44.20886	-100.39629
01/28/2010	150.900	female	adult	44.17381	-100.49550
01/28/2010	150.950	female	adult	44.17668	-100.43198
01/28/2010	150.970	female	adult	44.23000	-100.46717
01/28/2010	151.030	female	adult	44.13721	-100.44528
01/28/2010	151.050	female	adult	44.25264	-100.43248
01/28/2010	151.070	female	adult	44.12879	-100.27309
01/28/2010	151.090	female	adult	43.99966	-100.21894
01/28/2010	151.110	female	adult	43.99200	-100.29457
01/28/2010	151.130	female	adult	44.14153	-100.43890
01/28/2010	151.150	female	adult	44.11910	-100.29835
01/28/2010	151.170	female	adult	44.12060	-100.27815
01/28/2010	151.190	female	adult	44.18070	-100.54166
01/28/2010	151.360	female	adult	43.98911	-100.29493
01/28/2010	151.400	female	adult	43.98362	-100.39991
01/28/2010	151.410	female	adult	44.22200	-100.34871
01/28/2010	151.570	female	adult	44.27213	-100.44205
01/28/2010	151.630	female	adult	44.26296	-100.46052
01/28/2010	151.690	female	adult	44.21275	-100.49179
01/28/2010	151.880	female	adult	44.06815	-100.47072
01/28/2010	151.890	female	adult	43.99783	-100.22119
01/29/2010	150.030	female	adult	44.26924	-100.35355
01/29/2010	150.070	female	adult	44.27291	-100.35313
01/29/2010	150.340	female	adult	44.07534	-100.45464
01/29/2010	150.430	female	adult	44.02721	-100.50753
01/29/2010	150.450	female	adult	44.07363	-100.15209
01/29/2010	150.520	female	adult	43.97435	-100.39849
01/29/2010	150.550	female	adult	43.97503	-100.37658
01/29/2010	150.570	female	adult	44.10350	-100.24829
01/29/2010	150.620	female	adult	44.07750	-100.16350

Appendix B con't. Capture data for mule deer in Lyman, Stanley, and Jones Counties (FPNG), South Dakota, 2010-2012.

Capture Date	Frequency	Sex	Age	Latitude	Longitude
01/29/2010	150.710	female	adult	44.10635	-100.25140
01/29/2010	150.720	female	adult	44.11328	-100.17567
01/29/2010	150.740	female	adult	44.02555	-100.54875
01/29/2010	150.990	female	adult	44.09240	-100.14359
01/29/2010	151.490	female	adult	44.23576	-100.31262
01/29/2010	151.530	female	adult	44.23576	-100.31262
01/29/2010	151.600	female	adult	44.06960	-100.51968
01/29/2010	151.850	female	adult	44.07639	-100.52168
01/29/2010	151.870	female	adult	44.26170	-100.23623
02/21/2011	150.110	female	adult	44.08771	-100.26349
02/21/2011	150.240	female	adult	44.12793	-100.44097
02/21/2011	150.280	female	adult	44.00145	-100.19166
02/21/2011	150.570	female	adult	44.08941	-100.23446
02/21/2011	150.640	female	adult	44.26781	-100.24969
02/21/2011	150.680	female	adult	44.22011	-100.46429
02/21/2011	151.150	female	adult	44.29409	-100.36276
02/21/2011	151.170	female	adult	44.25682	-100.25250
02/21/2011	151.360	female	adult	44.06963	-100.54240
02/21/2011	151.880	female	adult	44.21757	-100.40961