GAME REPORT

Seasonal Movements of Elk Relative to Management Unit Boundaries in the Black Hills of South Dakota, 2007-2010.

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SEASONAL MOVEMENTS OF ELK RELATIVE TO MANAGEMENT UNIT BOUNDARIES IN THE BLACK HILLS OF SOUTH DAKOTA, 2007-2010

Completion Report

By

Lowell E. Schmitz, Ph.D.

Pittman-Robertson Project ---------- W-75-R

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ABSTRACT

SEASONAL MOVEMENTS OF ELK RELATIVE TO MANAGEMENT UNIT BOUNDARIES IN THE BLACK HILLS OF SOUTH DAKOTA, 2007-2010

Due to concerns about the declining elk (*Cervus elaphus*) population and the unknown movement of elk between unit boundaries, the South Dakota Department of Game, Fish and Parks placed a high priority on determining elk ecology within the Black Hills.

The objectives for this research were to: 1) document movements of elk relative to management unit boundaries; 2) identify movement corridors; and 3) document cause-specific mortality.

One hundred and five elk were captured and radio collared in the Black Hills of South Dakota. Elk were fitted with one of three types of collars, standard VHF, store-on-board GPS and live-uplink GPS. Fifty-one thousand, seven hundred and thirty-seven (51,737) locations were obtained to identify corridors and movements across and within units. Results have shown 73% of collared elk to utilize more than one Game Management Unit (GMU) throughout the year and that over 30% of collared elk were located in more than one GMU during the hunting seasons. Five distinct corridors/crossings were found which elk utilized to cross from one GMU to the next. Annual home range for cow elk was

140.3 km^2 (SE $\pm$ 23.9). Elk selected for canopy cover $\leq$ 38% and avoided canopy cover $\geq$ 86%. Elk also selected for slopes $\leq$ 30% and avoided areas with slope $\geq$ 50%. Total mortality during the 3 year study was 63%. Annual mortality was 35%, 35% and 49% for 2007, 2008, and 2009 respectively. Total mortality among bulls was 68% (17 of 25) and 60% (45 of 74) for cows. Hunters accounted for 77% of the mortalities (66% harvest, 11% wounding loss) and predation accounted for $\geq$ 11%.

Elk populations cannot sustain the harvest mortality that has been documented in this study. Management recommendations include: 1) utilize aforementioned mortality rates from this study for the population model and adjust permits accordingly and 2) due to the number of elk moving between GMU's it is essential to look closely at canopy cover, slope, harvest rates and management objectives to determine if GMU boundaries should be altered.

PREFACE

This report summarizes results of research conducted by South Dakota Department of Game, Fish and Parks personnel during 1 January 2007 – 1 May 2010 on mortality and movements of elk in the eastern Black Hills of South Dakota (study No. 7586 under Pittman-Robertson project W-75-R).

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INTRODUCTION

Elk (*Cervus elaphus*) are a highly desirable species for both consumptive and non-consumptive users in the Black Hills and elsewhere (Bunnel et al. 2002). Elk once inhabited all of South Dakota from the mixed grass prairie regions in the east to the western ponderosa pine forests of the Black Hills. By the late 1800s elk were extirpated in South Dakota (Rice 1988); however, in the early 1900s, efforts were underway to re-establish elk in South Dakota. By 1988, the elk population was estimated at nearly 1,000 animals with herds established throughout the Black Hills National Forest, Custer State Park, Wind Cave National Park, and private land in the Black Hills (Rice 1988). Populations continued to increase and by 2004 the elk population was estimated at 4,600 outside the parks (Huxoll 2004). Currently within the Black Hills, elk are found in the Black Hills National Forest, Custer State Park, Wind Cave National Park and private land in the Black Hills. The Wildlife Division of the Department of Game, Fish and Parks is entrusted to manage all elk outside of the park systems. Presently, South Dakota's elk population within the Black Hills is estimated at approximately 3,200 (John Kanta, personal communication 2010).

Elk are currently managed under a 7 Game Management Unit (GMU) system within the Black Hills (Figure 1).

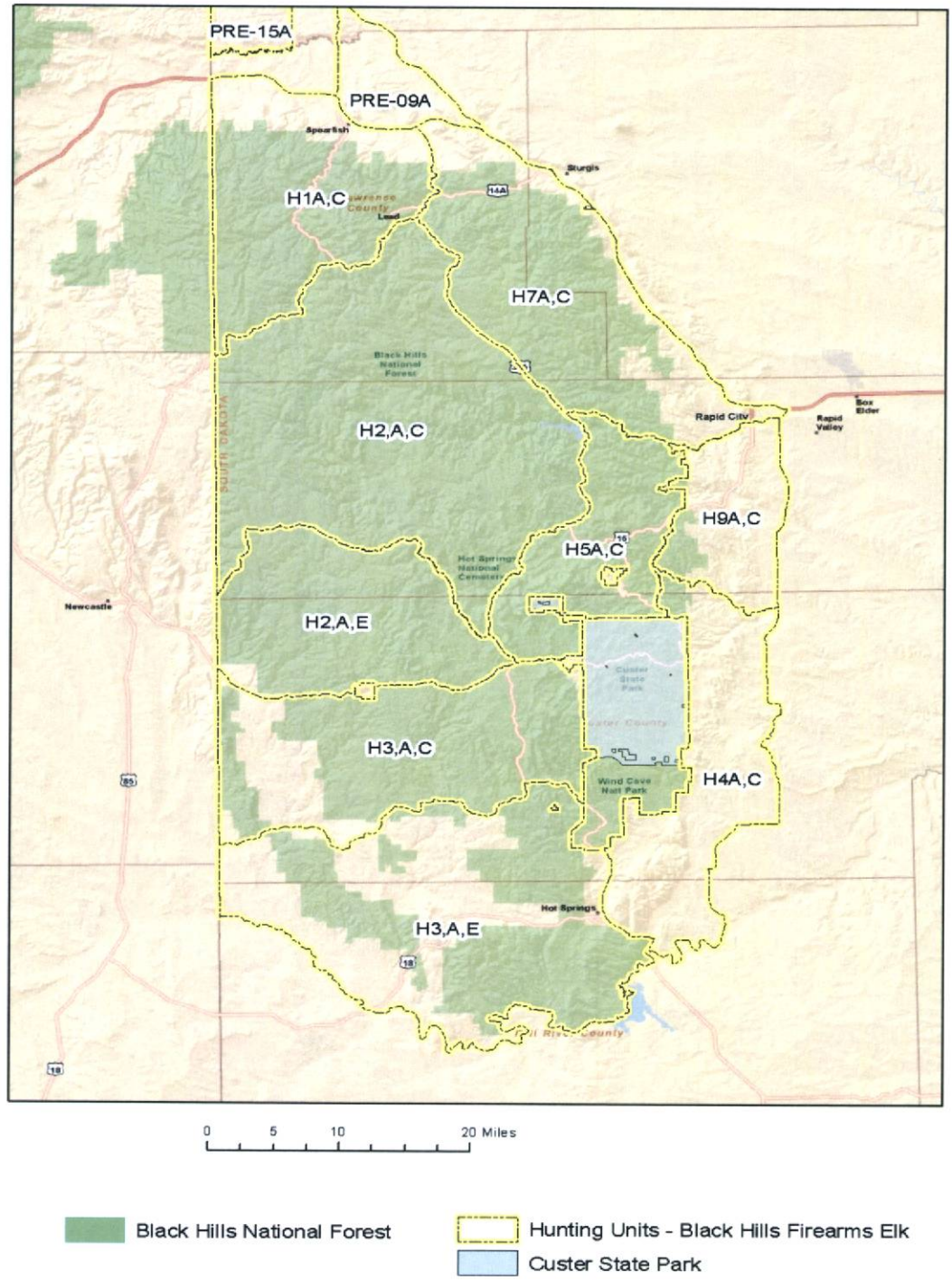

Figure 1. Elk Game Management Units in the Black Hills of South Dakota, 2007 – 2010.

Little information is available on elk movements across and within unit boundaries. Some elk populations are known to take long seasonal migrations while others are non-migratory (Peek 1982). The need to enhance individual fitness by acquiring adequate resources while minimizing predation risk is the driving force in habitat selection (Conrad 2009). In areas with large predators present, habitat selection by ungulates is influenced by predation risk at the landscape level, while habitat selection within the home range is related to forage and water availability (Rettie and Messier 2000, Skovlin et al. 2002, Anderson et al. 2005). Burt (1943) defined home range as the area traversed by the individual in its normal activities of food gathering, mating, and caring for young. Elk home ranges have been studied in Wind Cave National Park (Bauman 1998), Custer State Park (Millspaugh 1995) and along the western edge of the Black Hills of South Dakota (Benkobi et al. 2005).

Elk exhibit a variety of seasonal movements, including migratory (Boyce 1989) and non-migratory behavior (Rice 1988) throughout the western United States. Migrations are usually governed by weather and food availability. In South Dakota, elk are an extremely popular wildlife species for both consumptive and non-consumptive users. Furthermore, excluding hunter harvest, elk mortality rates are largely unknown in the Black Hills. Management practices directly influence the impact of human related mortality on elk survival rates (Conrad 2009). Harvest success and rates depend largely on the total number of permits issued, hunter access, and road density (Edge 1982, Wright 1983).

The demand for hunting licenses far exceeds the supply. For the 2010 Black Hills firearm elk season, 14,674 individuals applied for the 1,065 available licenses. In addition, Custer State Park had 24,574 applicants for 60 elk licenses (Corey Huxoll, personal communication 2010). Due to concerns about the declining elk population and the unknown movement of elk between unit boundaries, the South Dakota Department of Game, Fish and Parks placed a high priority on determining elk ecology within the Black Hills.

The objectives of this study were:

1. To document movements of elk relative to management unit boundaries.
2. To identify movement corridors.
3. To document cause specific mortality of elk in the Black Hills.

STUDY AREA

The Black Hills are an isolated, mountainous extension of the Rocky Mountains (Peterson 1984) located in western South Dakota and northeastern Wyoming surrounded by grassland and sagebrush (*Artemisia sp.*) steppe ecosystems (Peterson 1984, Larson and Johnson 1999). Covering an area of approximately 8,400 km^2 (Fecske and Jenks 2002), the Black Hills extend approximately 95 km east to west and 190 km north to south (Peterson 1984). Elevations range from 973 – 2,202 m above mean sea level (Turner 1974). Orr (1959) noted that the Black Hills have seasonal temperature fluctuations typical of a continental climate. Mean annual temperatures range from 5 to 9^0C with extremes of -40 to 44^0C (Thilenius 1972). Yearly snowfall may exceed 254 cm at

higher elevations (Thilenius 1972) with mean annual precipitation ranging from 45-66 cm (Orr 1959).

Elk are found scattered throughout the forests of the Black Hills and occur sympatrically with white-tailed deer (*Odocoileus virginianus*) and mule deer (*O. hemionus*) (Deperno 1998, Schmitz 2010). Primary predator of elk are mountain lions (*Puma concolor*). The study area encompassed approximately 3,636 km^2 and covered five elk Game Management Units (GMU's), including the northern portion of GMU's 4, and 5, GMU 7, GMU 9 and the eastern portion of GMU 2 in the eastern Black Hills of South Dakota (Figure 2). The public land is managed by the USDA Forest Service interspersed with private lands. Within the study area, private lands comprise a range of 12% (GMU 2) to 98% (GMU 4) of each GMU (John Broecher, personal communication 2010). Ponderosa pine (*Pinus ponderosa*) is the dominant coniferous tree species, comprising roughly 80% of the overstory canopy; aspen (*Populus tremuloides*) is the most abundant deciduous tree species (Rumble and Anderson 1993). Canopy cover ranged from 0-100% which increased south to north along a precipitation and elevation gradient (Jarding 2010).

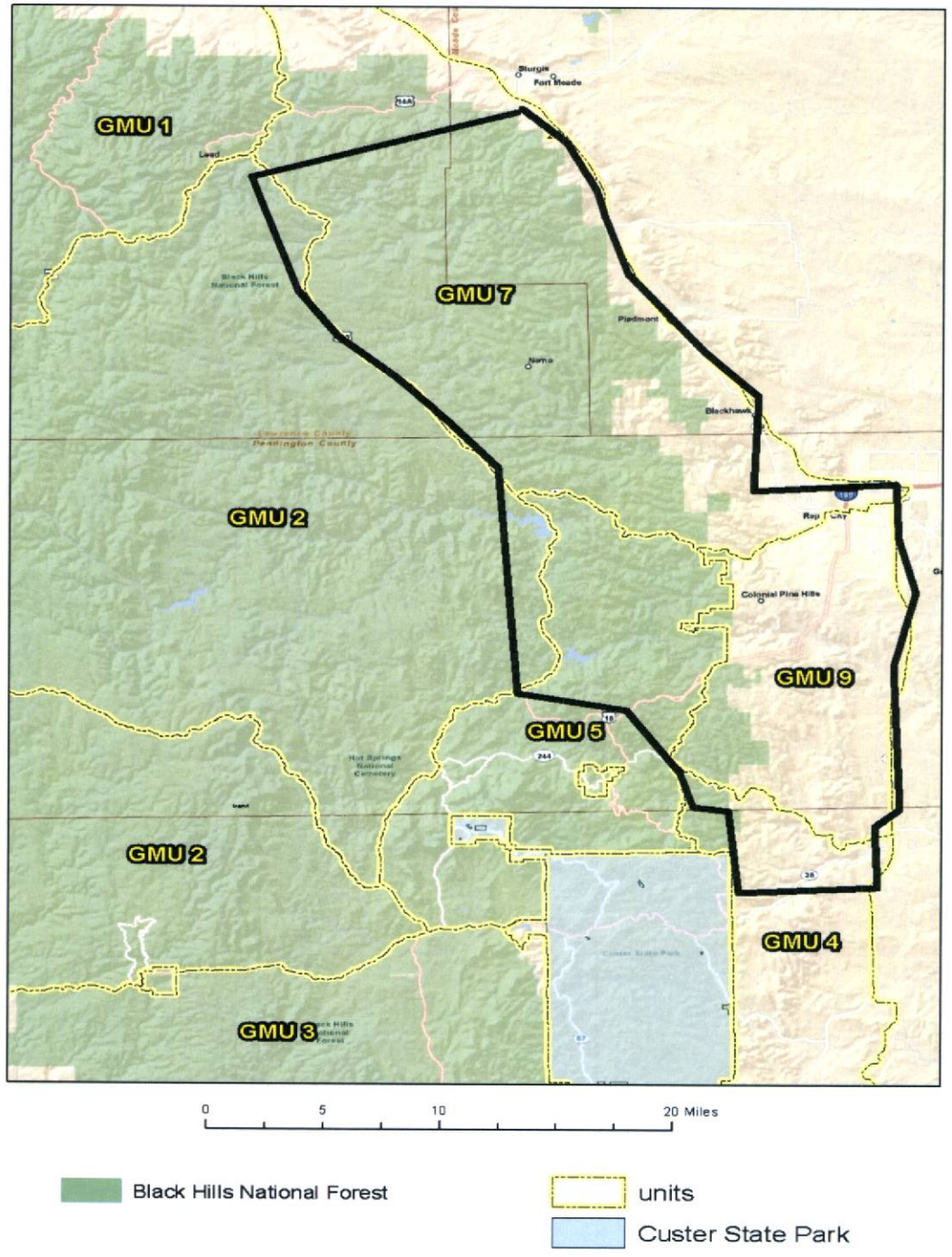

Figure 2. Elk study area located in the eastern Black Hills of South Dakota, 2007 – 2010.

METHODS

Elk Capture:

Elk were captured in January and February of 2007, and January through April of 2008 and 2009. Elk were either net-gunned or darted from a helicopter using a Mod 500 in 2007 and a Robinson-44 (Quicksilver Air, Peyton, Colorado) in 2008 and 2009. Additional elk were captured by darting from ground blinds or tree stands set up over bait sites. Due to high canopy cover, bait sites were set up in the northern part of the study area to lure the elk to open edges to assist in the capture. In 2007, each drugged elk was immobilized with Carfentanil Citrate and reversed with Naltrexone HCL. BAM, a combination of Butorphanol, Azaperone and Medetomidine, was used to immobilize elk in 2008 and 2009. BAM was reversed using a mixture of Antisedan, Naltrexone, and Tolazoline (Mich et al. 2008).

Radio Telemetry:

Elk were fitted with one of three types of radio collar, standard VHF (n = 83), store-on-board GPS (n = 17) and live-uplink GPS collars (n = 5). The VHF transmitters were Telonics (Telonics, Mesa, Arizona) Mod-601 NH elk collars equipped with a MS6A mortality sensor (4 hour delay). Also used were Telonics - Gen. III "store-on-board" global positioning system (GPS) model # TGW-3600 collars. The store-on-board collars were equipped with a CR-2A release mechanism set for February 2010 as well as a MS6A mortality sensor

(4 hour delay). In order to conserve battery life, the VHF beacon on these collars operated ten hours on and fourteen hours off. The collars took six locations a day (4 hour intervals). The third type of collar was the North Star (North Star Science and Technology, LLC, King George, Virginia) Live-uplink GPS collar Model NSG-LD2. These collars were also programmed to take six locations a day (4 hour intervals). Radio-collared elk were located 1-5 times per week by ground visual observations and or from the air using a Telonics Model TR-2 receiver (Telonics, Mesa, Arizona). Ground tracking was conducted using a 2-element H-antenna (Telonics, Mesa, Arizona) and aerial tracking was conducted by fixed wing aircraft. Active tracking and monitoring ended 1 May 2010.

All locations were converted to Universal Transverse Mercator (UTM) coordinates (North American Datum 1983, Zone 13) and were entered into ArcMap (ESRI ArcMap 9.3) for analysis of the data. Two subsets of the elk location data corresponding to summer (June to August) and winter (January to March) were chosen to directly compare home ranges found by Benkobi et al. (2005). Percent slope was derived from the 1 arc-second National Elevation Dataset (NED) using the ESRI ArcMap Spatial Analyst Surface Analysis tool (Gesch et al. 2002, Gesch 2007). Percent canopy cover was obtained from the U.S. Geological Survey National Land Cover Database Zone 31 Tree Canopy Layer (Huang et al. 2001, Homer et al. 2004).

Statistical analysis

Survival rates of elk were calculated using the Kaplan-Meier procedure (Kaplan and Meier 1958) modified for a staggered entry design (Pollock et al. 1989). Elk were censored from analysis if collars malfunctioned. Survival rates were compared by year and sex using Program CONTRAST (Hines and Sauer 1989); alpha was set at $P \leq 0.05$.

Monthly home range size and distance traveled between data points were calculated using HRT: Home Range Tools for ArcGIS version 1.1 (Rodgers and Kie 2010). Seasonal home ranges were estimated by using the 95% kernel use distribution (Hooge et al. 1999) with least squares cross-validation (Seaman et al. 1999) in ArcView 9.3 (Environmental Systems Research Institute, Inc. 2010). A repeated measures analysis (Zar 1999) was used to compare home ranges in SYSTAT 10.0 (SPSS Inc., Chicago Illinois). Slope and canopy cover were calculated using Design 1 (Manley et al. 2003). A chi-square test goodness-of-fit was performed to determine if canopy and slope were equally preferred (Jelinski 1991).

RESULTS

Elk Capture:

One hundred and five elk were captured and radiocollared. In the event of mortality the collar was re-deployed on another elk the following year. In January and February of 2007, a total of 49 elk were captured and fitted with radio collars. These forty-nine elk consisted of 10 bulls and 39 cows. The 10 bulls were fitted with VHF collars. Ten of the cow elk were fitted with store-on-board GPS collars.

One cow elk was fitted with a live-uplink collar and the remaining 28 cows were fitted with VHF collars. Elk were captured at four areas (Figure 3).

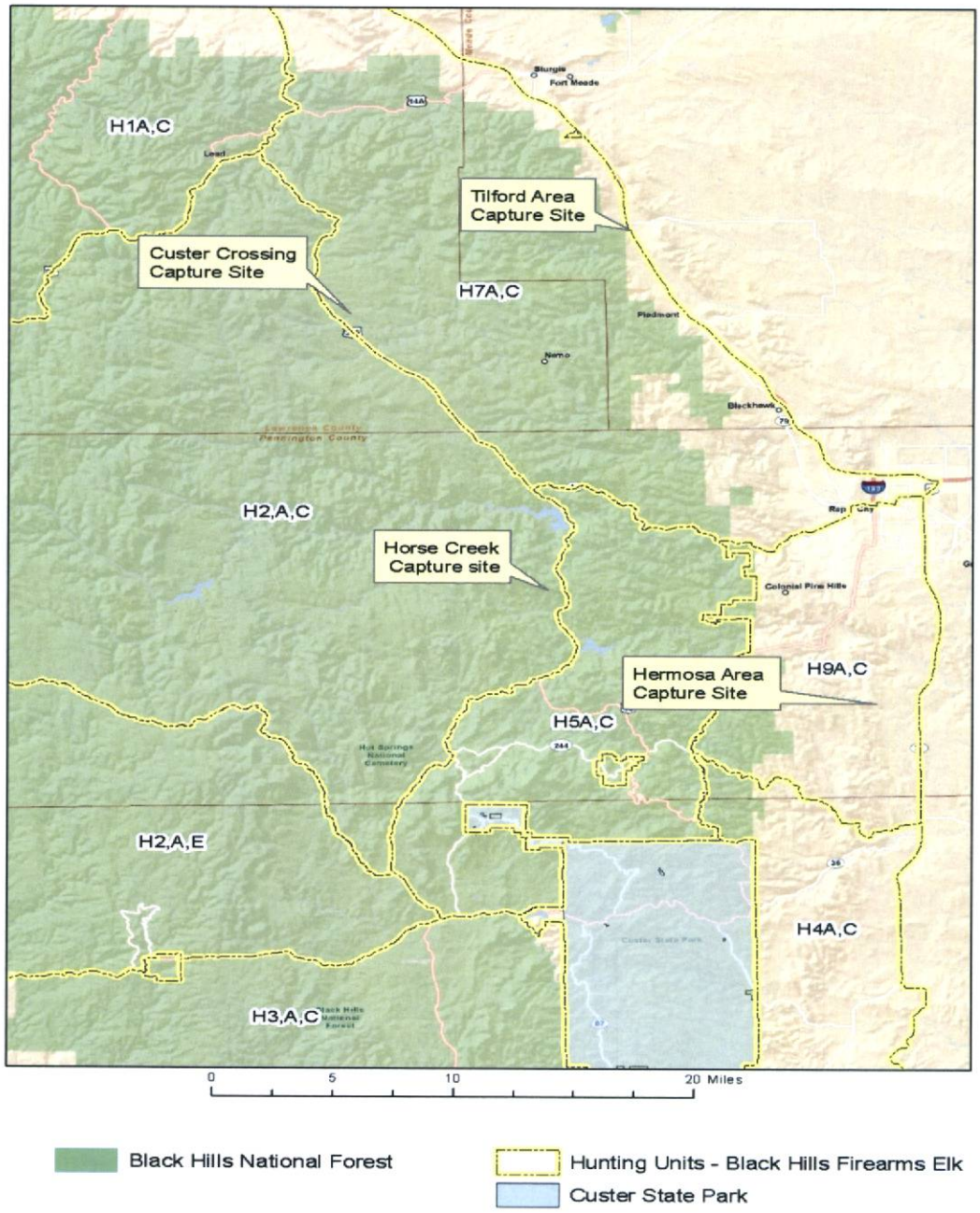

Figure 3. Elk capture sites in the Black Hills of South Dakota, 2007-2009.

At the southern most capture site, near Hermosa, 26 elk (5 bulls, 21 cows) were captured and collared. Along Highway 385 near Custer Crossing, six elk (4 bulls, 2 cows) were captured and collared. At the Horse Creek capture sight, five elk (0 bulls, 5 cows) were collared. Near Sturgis, the Tilford area capture site, 12 elk (1 bull, 11 cows) were captured and collared.

In February, March and April of 2008, an additional 25 elk were captured and fitted with radio collars. These twenty-five elk consisted of 6 bulls and 19 cows. Two of the bulls were fitted with Live-uplink GPS collars and the other 4 with VHF collars. One cow was fitted with a Live-uplink GPS collar, 6 cows with store-on-board GPS collars and the remaining 12 cows were each fitted with VHF collars. Elk were captured at two areas. At the southern most capture site, near Hermosa, 14 elk (2 bulls, 12 cows) were captured and collared. Along Highway 385 near Custer Crossing ten elk (4 bulls, 7 cows) were captured and collared.

In January, February, March and April of 2009, an additional 31 elk were captured and fitted with radio collars. These thirty-one elk consisted of 13 bulls and 18 cows. One bull had its malfunctioning Live-uplink collar replaced and the other 12 bulls were fitted with VHF collars. One cow was fitted with a store-on-board GPS collar and the remaining 17 cows were fitted with VHF collars. Elk were captured at three areas. Near Hermosa, 8 elk (5 bulls and 3 cows) were captured and collared. Near Rockerville, 5 elk (3 bulls, 2 cows) were captured and collared. Along Highway 385 near Custer Crossing, 18 elk (5 bulls, 13 cows) were captured and collared.

Elk Locations:

Over the course of the study 51,737 locations were used to determine the movements within and across unit boundaries. However, for accuracy purposes only the 50,486 GPS locations were plotted to determine movements (Figure 4).

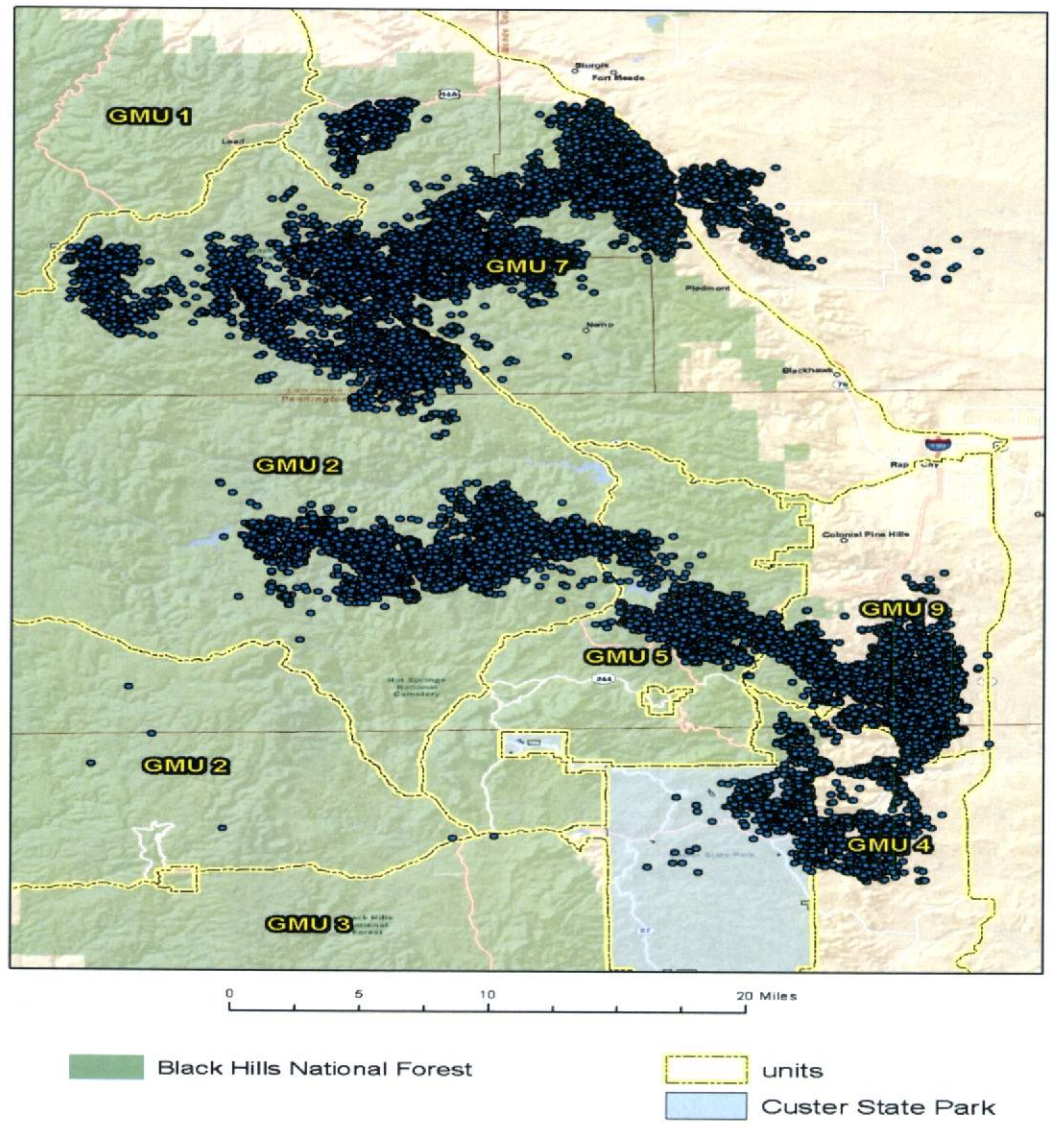

Figure 4. GPS elk locations (n = 50,486) in the Black Hills of South Dakota, 2007 - 2010.

The store-on-board GPS collars had a 97% successful fix rate, and accounted for 45,454 of the locations. The live-uplink collars had a 71% successful fix rate and provided 4,412 locations. The VHF collars yielded 620 visual locations via ground and air telemetry. In addition to specific locations, 1,251 GMU specific locations were obtained for a total of 51,737 recorded locations.

Seventy-three percent (69 of 94) of collared elk utilized more than one GMU throughout the year. Forty percent (n = 38) of the collared elk utilized 2 GMU's. Nineteen percent (n = 18) of the collared elk utilized 3 GMU's, thirteen percent (n = 12) utilized 4 GMU's and one elk was located in 5 different GMU's. Elk locations were categorized by time and GMU specific locations (Table 1) (Appendix A).

All data was used to determine locations in each GMU during seasonal periods. These periods were the month of September, when the archery season was held; the month of October, when the rifle season was held; and the first two weeks of December, when the late anterless season was held.

In September, locations were acquired on 42 collared elk (Appendix B). Seventy percent of the collared elk remained in one GMU while 30% were located in two different GMU's in September.

In October, locations were acquired on 69 collared elk (Appendix C). Sixty-two percent of the elk were located in a single GMU while 38% were located in at least two different GMU's during the rifle season.

In December, locations were acquired from 58 radio collared elk (Appendix D). Sixty-one percent of the elk were found in only one GMU while 39% were found in two or more different GMU's.

Calving dates, the last week of May and the first week of June, were evaluated to determine which GMU the cow elk were using during the calving season (Figure 5) (Appendix E). Of the 54 radiocollared cows located during the calving period 71% utilized a single GMU while 25% were located in at least two GMU's, and 4% were located in at least three different GMU's.

Table 1. Collared elk locations in the Black Hills of South Dakota, 2007 – 2010.

Time	Total	GMU 2	GMU 4	GMU 5	GMU 7	GMU 9	CSP
Annual	51,737	10,360	2,624	5,575	19,177	11,590	1,123
September	4,154	994	196	392	1,675	893	1
October	3,657	992	137	511	1,246	699	1
December	1,521	458	18	154	413	384	15
May/June [1, 2]	2,674	381	104	436	1,128	620	5

[1] Cow elk only 2007 - 2009.

[2] Last week of May, first week of June which corresponds to calving dates.

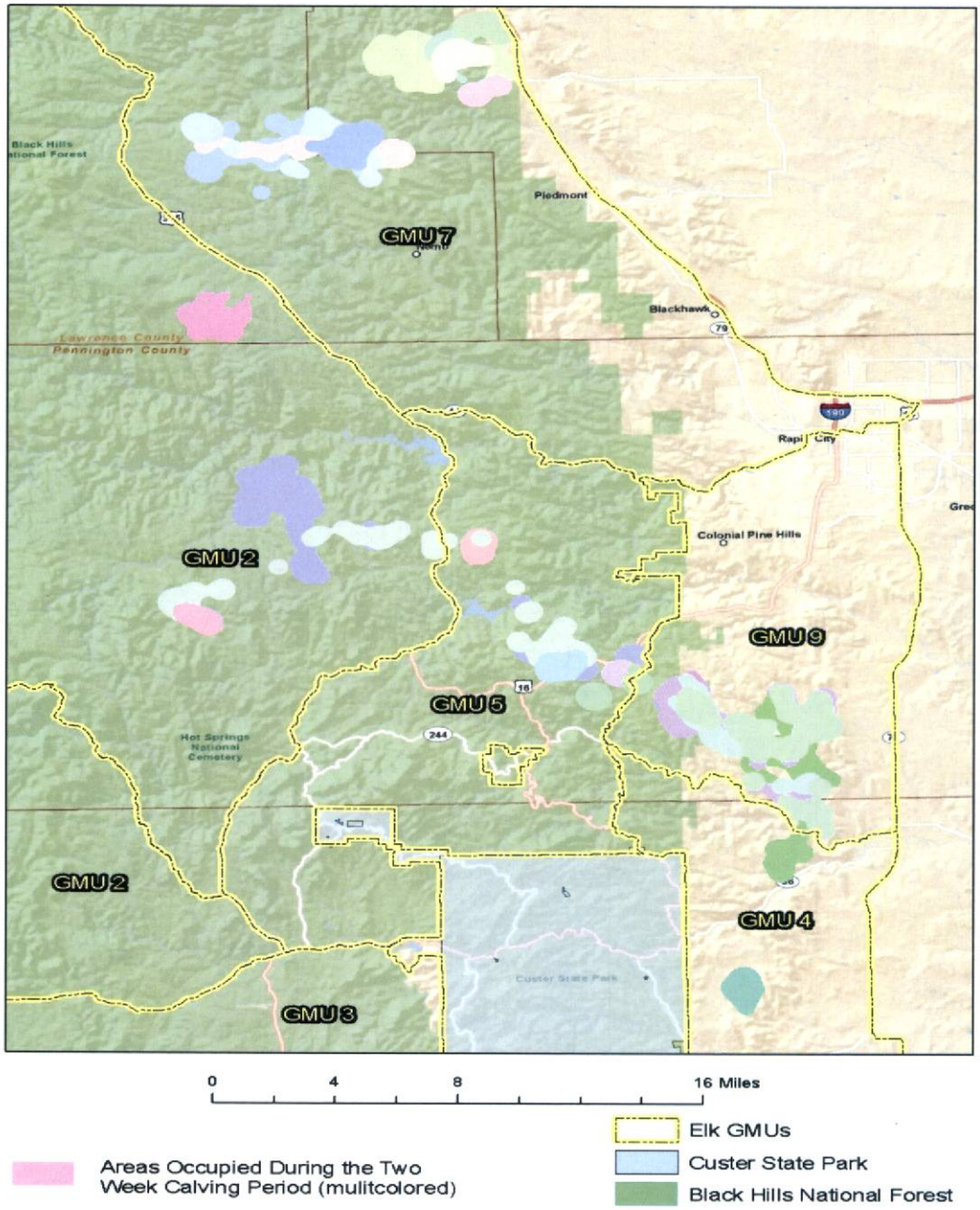

Figure 5. Locations of GPS collared cow elk the last week of May and the first week of June in the Black Hills of South Dakota, 2007 - 2009.

For cow elk with store-on-board GPS collars (n = 17), 53% of their locations occurred on NFS, 45% on private land, and 2% were outside of any GMU. During September these same cows utilized the same areas with 56% of the locations on NFS, and 44% on private land. In October, the elk locations were 54% on NFS, and 46% on private land. For the first two weeks of December, 51% of the locations were on NFS and 49% on private land. For the calving season, 72% of the locations occurred on NFS and 28% on private lands.

Thirty-three percent of the locations acquired from nine GPS store-on-board collared cows in GMU 7 were on private property. Fifty-five percent of the locations acquired from eight GPS store-on-board collared cows in GMU's 4 & 9 were on private property.

Home ranges were calculated from the 17 cow elk fitted with store-on-board GPS collars. Yearly home range size for collared cows (n = 10) was 140.3 km^2 (SE $\pm$ 23.9). Home range size between collared cows in the northern and southern groups differed (F = 3.214, $d.f.$ = 11, 99, P = 0.001). Cows in the southern portion of the study area (n = 6) had a home range size of 169.2 km^2 (SE $\pm$ 34.9) while those in the northern portion (n = 4) had a home range of 97.1 km^2 (SE $\pm$ 13.1). Seasonal home range size did not differ (F = 0.609, $d.f.$ = 1, 9, P = 0.455). Seasonal home ranges for elk were 43.9 km^2 (SE $\pm$ 4.7) for summer (n = 17) and 55 km^2 (SE $\pm$ 9.4) for winter (n = 10). Elk had the smallest home range in June and the largest in October (Figure 6). Annual movements by elk averaged 515 meters per four hour fix interval.

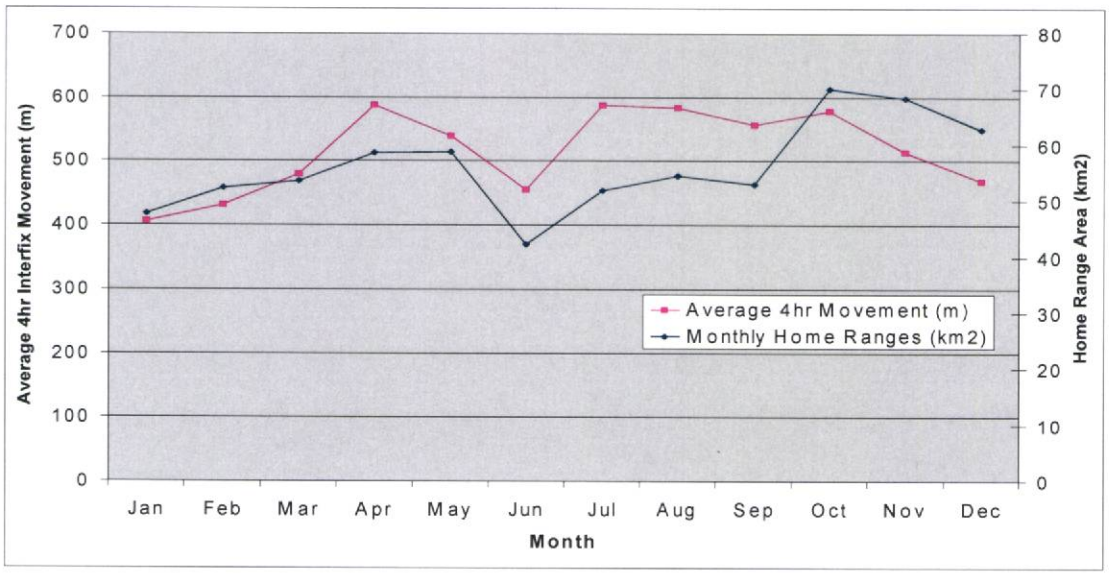

Figure 6. Average 4hr fix interval compared to monthly home range of GPS radio collared cow elk in the Black Hills of South Dakota, 2007 - 2010.

Cow elk (n = 17) selected for canopy cover below 38% ($\chi^2_1 = 2243.58$, $P < 0.0001$) and avoided canopy cover of greater than 90% (Figure 7).

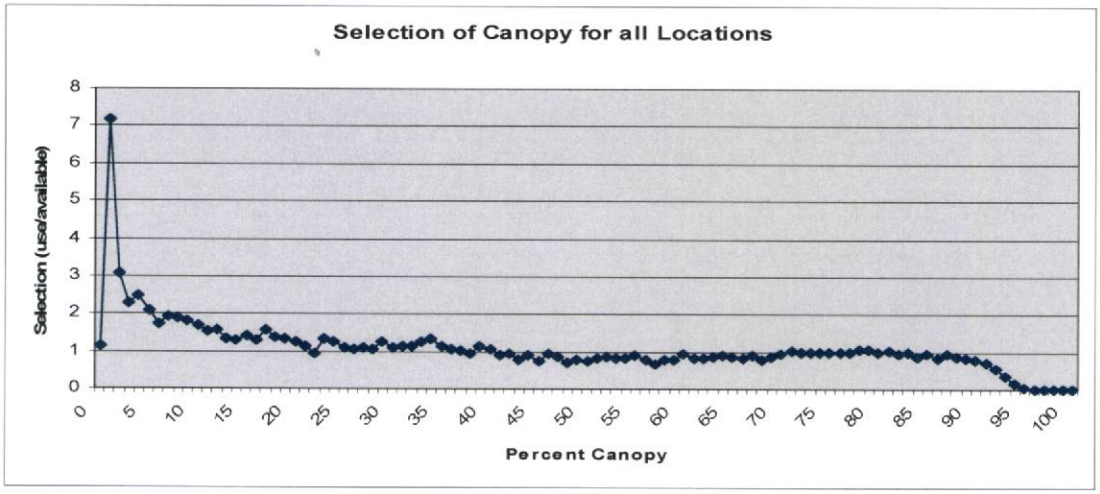

Figure 7. Selection of canopy by GPS radio collared cow elk in the Black Hills of South Dakota, 2007 - 2010.

Cow elk (n = 17) selected for slope of 30% or less ($\chi^2_1 = 1998.55$, $P < 0.0001$) and avoided areas of 75% or greater ($\chi^2_1 = 62.43$, $P < 0.0001$) (Figures 8 and 11).

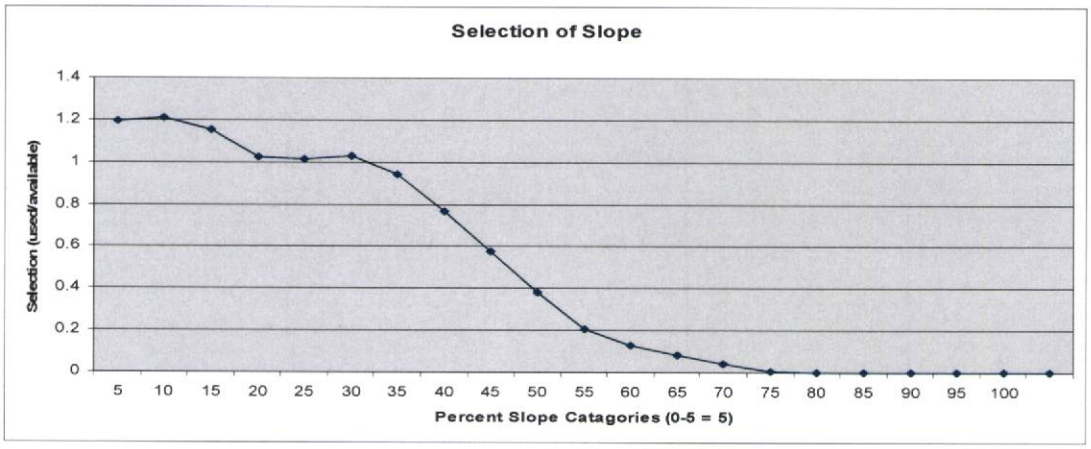

Figure 8. Selection of slope by GPS radio collared cow elk in the Black Hills of South Dakota, 2007 - 2010.

However, during the calving season, cow elk preferred canopy cover areas between 28 and 86% ($\chi^2_1 = 333.53$, $P < 0.0001$) (Figure 9) and selected areas of slope of between 15 - 40% ($\chi^2_1 = 120.01$, $P < 0.0001$) (Figures 10 and 12).

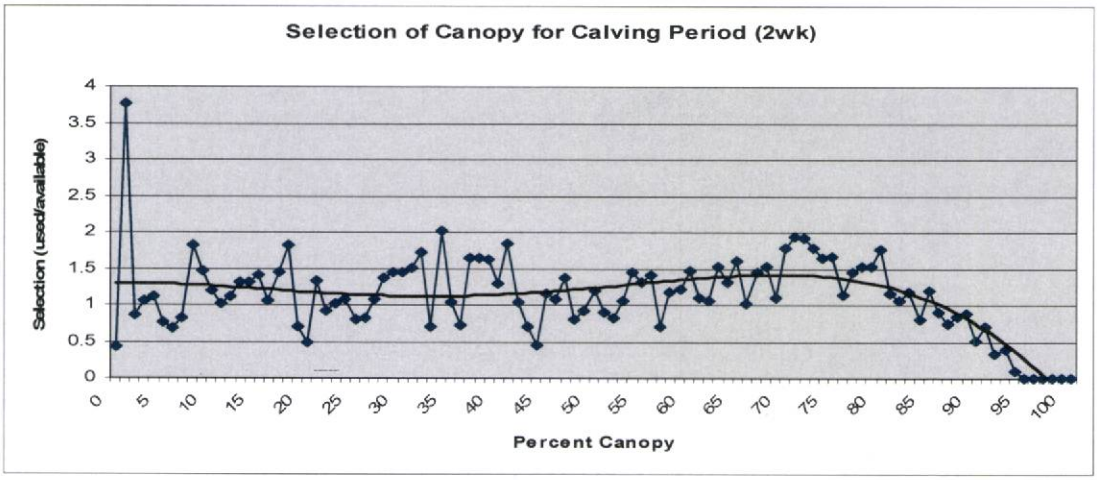

Figure 9. Selection of canopy during the two week calving period for GPS radio collared cow elk in the Black Hills of South Dakota, 2007 - 2009.

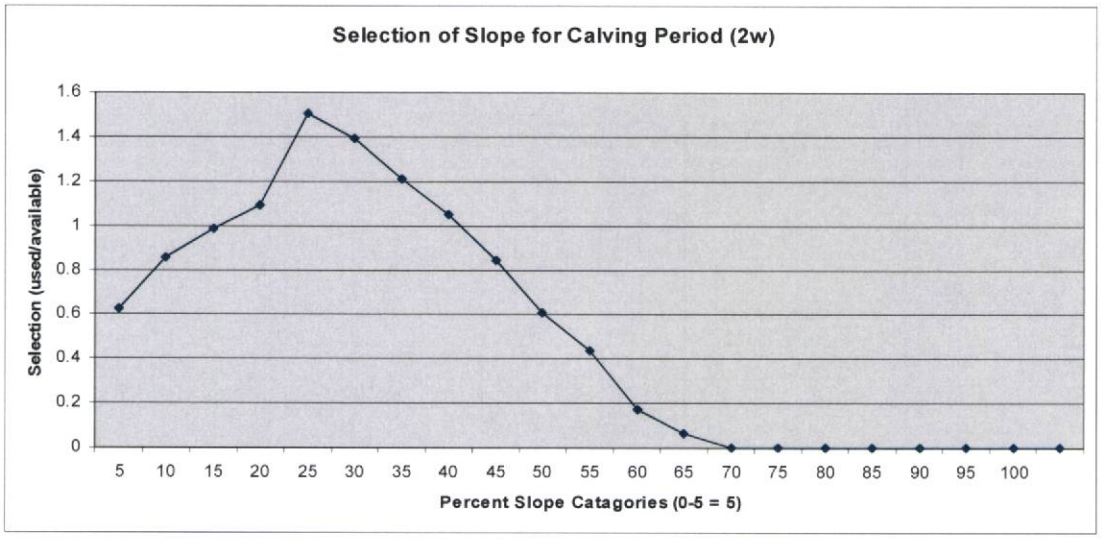

Figure 10. Selection of slope during the two week calving period for GPS radio collared cow elk in the Black Hills of South Dakota, 2007 - 2009.

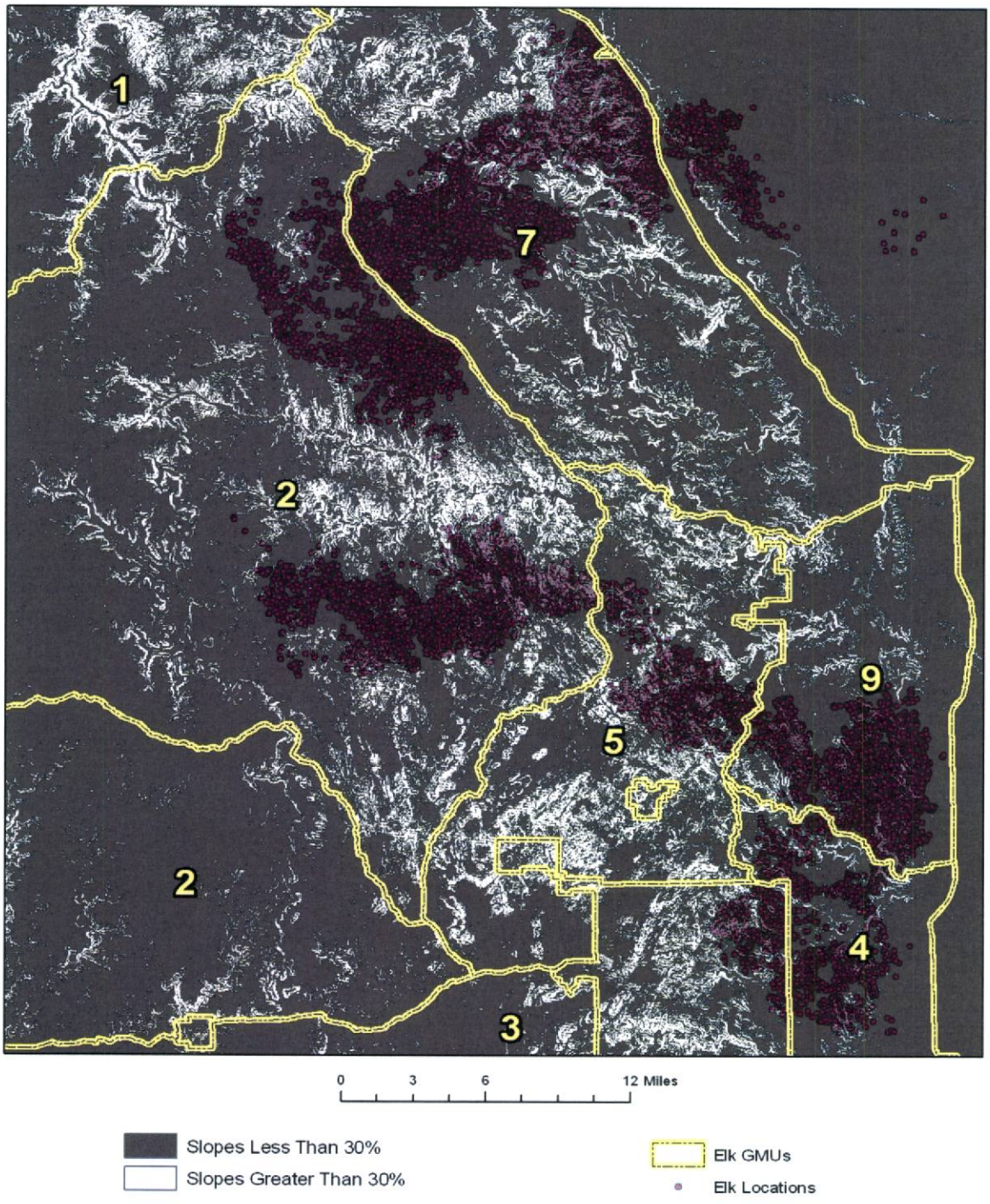

Figure 11. Elk locations in relation to slope of the Black Hills of South Dakota, 2007-2010.

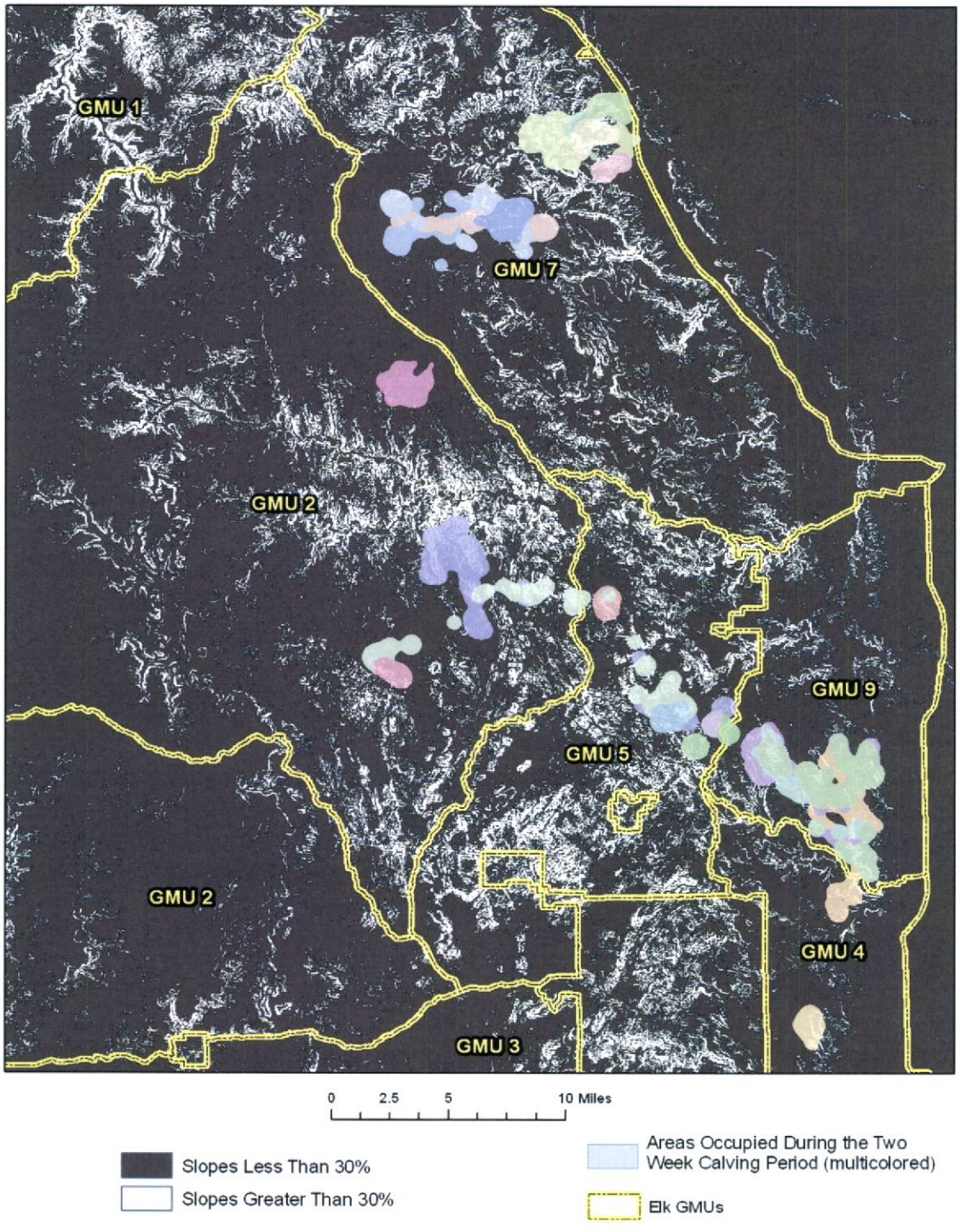

Figure 12. GPS collared cow elk (n = 17) locations during calving in relation to slope in the Black Hills of South Dakota, 2007-2009.

Elk corridors:

Five distinct corridors between GMU's were apparent when mapping the location data (Figure 13). Corridors tended to follow terrain with slope of less than 25%. Twenty three collared elk moved between GMU's 2 and 7 along the Hwy 385 Custer Crossing (Appendix F). Four collared elk moved across the Tilford Crossing which was located along Interstate 90 near the Tilford Exit (Appendix G). The Horse Creek Crossing was along Hwy 385 near Horse Creek and allowed the elk (n = 17) to travel between GMU's 5 and 2 (Appendix H). The South Rockerville Road Crossing allowed the collared elk (n = 29) to move between GMU's 9 and 5 (Appendix I). The Hwy 40 Crossing was located west of Hermosa along Highway 40 and allowed movement of 22 collared elk between GMU's 4 and 9 (Appendix J). The CSP Crossing was located along the eastern border of CSP and allowed 16 collared elk to move between CSP and GMU 4 (Appendix K).

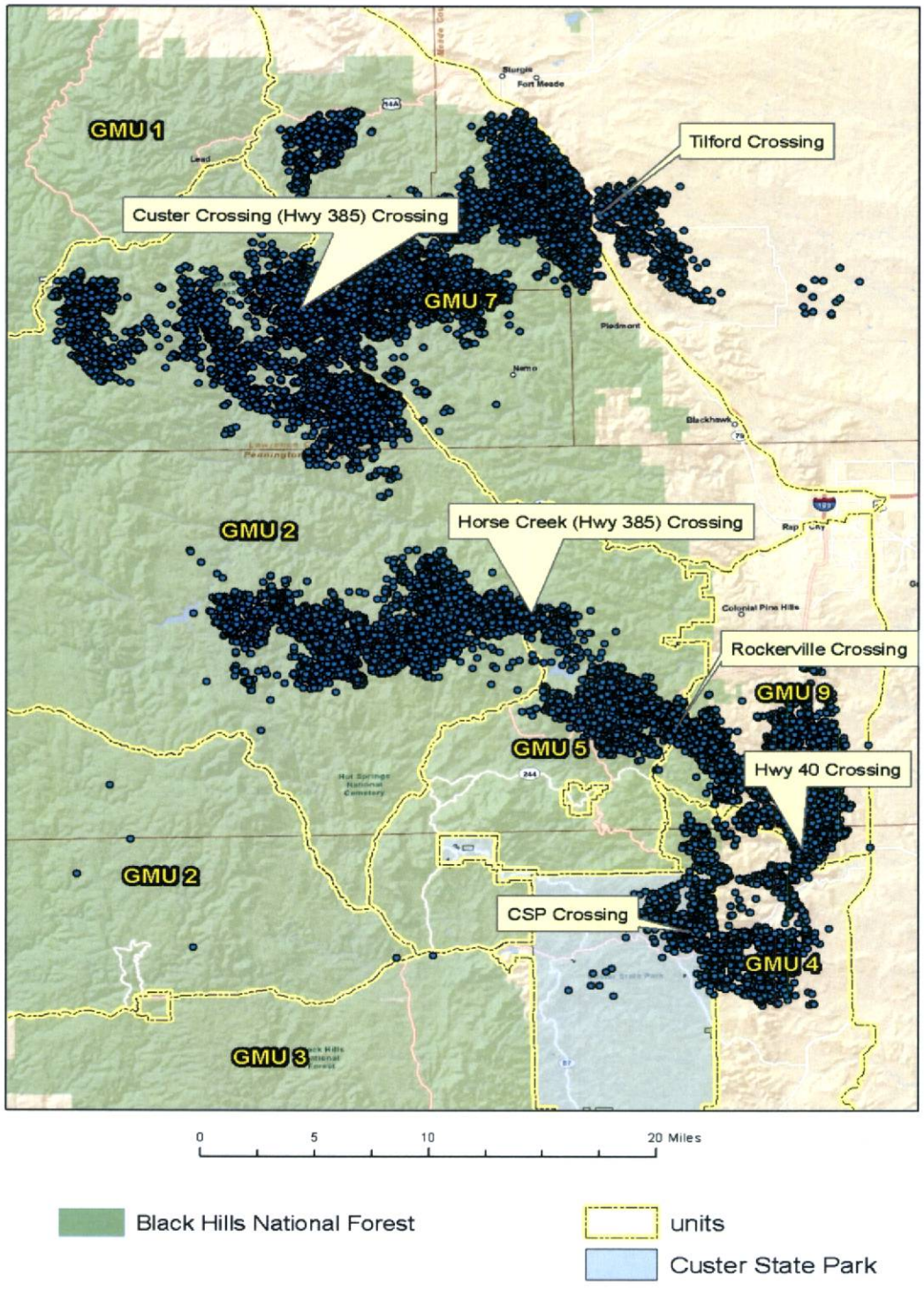

Figure 13. Elk corridors between GMU's in the Black Hills of South Dakota, 2007-2010.

Elk Mortality:

Four capture mortalities occurred in 2007. Mortalities included 1 bull and 3 cows. Each elk suffered a broken leg during capture. There were no capture related mortalities in 2008 or 2009.

Mortalities in 2007 included hunter harvest 8 (1 bull, 7 cows); wounding loss 4 (0 bulls, 4 cows); 2 mountain lion kills (0 bulls, 2 cows); 4 unknowns (1 bull, 3 cows); and 1 removal due to collar malfunction (0 bulls, 1 cow). Total mortality for 2007 was 35% (Table 2).

Mortalities in 2008 included hunter harvest 15 (4 bulls, 11 cows); wounding loss 2 (1 bull, 1 cow); and 2 road kill (1 bull, 1 cow). Three collars malfunctioned and were censored from analyses. Total mortality for 2008 was 35% (Table 2).

Mortalities in 2009 included hunter harvest 18 (9 bulls, 9 cows); wounding loss 1 (0 bulls, 1 cow); road kill 1 (0 bulls, 1 cow): 5 mountain lion kills (0 bulls, 5 cows) and 1 unknown (0 bulls, 1 cow). One additional collar malfunctioned and was censored. Total mortality for 2009 was 49% (Table 2).

Hunter harvest accounted for the greatest proportion of mortality during all 3 years of study: 47%, 79%, and 69% in 2007, 2008, and 2009, respectively. Minimum total mortality for the three years of this study was 63%. Mortality among bulls was 68% (17 of 25) and 60% (45 of 74) for cows. Of the total mortality, hunters accounted for 77% (66% harvest, 11% wounding loss) and predation accounted for a minimum of 11%.

Table 2. Cause-specific mortality of radiocollared elk in the Black Hills of South Dakota, 2007 - 2009.

Season	2007	2008	2009
Number at-risk	49	55	64
Hunter Harvest	8	15	18
Wounding Loss	4	2	1
Mountain Lion Predation	2	0	5
Road Kill	0	2	1
Unknown Mortality	4	0	1
Collar Malfunction	1	3	1

Survival:

Annual survival rates for collared elk were 0.63 (n = 49 SE= 0.01), 0.65 (n = 55, SE = 0. 10), 0.59 (n = 64, SE = 0.01) for 2007, 2008 and 2009, respectively (Table 3). Overall, there was no significant differences ($\chi^2_2 = 0.24$, $P = 0.89$) in survival between years, and bull survival rates did not differ ($\chi^2_1 = 2.4$, $P = 0.12$) from cow survival. However, there was a significant difference ($\chi^2_1 = 7.3$, $P = 0.0068$) in bull survival when comparing 2007 to 2008 and 2009. Bull survival in 2008 and 2009 also differed ($\chi^2_1 = 15$, $P > 0.001$) from cow survival compared to all three years (Tables 4 and 5).

Table 3. Annual survival rates for radiocollared elk in the Black Hills of South Dakota, 2007-2009.

	2007	2008	2009
Number at-risk	49	55	64
Number of deaths	18	19	26
Number censored	1	3	1
Survival Rate	0.6327	0.6545	0.5938
Confidence interval (95%)	±0.1074	±0.1016	±0.0928
Variance	0.0030	0.0027	0.0022

Table 4. Annual survival rates for radiocollared bull elk in the Black Hills of South Dakota, 2007-2009.

	2007	2008	2009
Number at-risk	10	14	19
Number of deaths	1	6	9
Number censored	1	2	1
Survival Rate	0.9000	0.5714	0.5263
Confidence interval (95%)	±0.1764	±0.1959	±0.629
Variance	0.0081	0.0100	0.0069

Table 5. Annual survival rates for radiocollared cow elk in the Black Hills of South Dakota, 2007-2009.

	2007	2008	2009
Number at-risk	39	41	45
Number of deaths	17	13	17
Number censored	0	1	0
Survival Rate	0.5641	0.6829	0.6222
Confidence interval (95%)	±0.1169	±0.1177	±0.1117
Variance	0.0036	0.0036	0.0033

DISCUSSION

Elk Locations:

The two types of GPS collars accounted for 98% of the usable locations. However for data analyses only the 17 store-on-board GPS collar data was utilized. Due to collar malfunctions, there were not enough comparable data from the five live-uplink GPS collared animals to draw any sound conclusions. There were a total of 620 visual observations recorded for elk with standard VHF collars. In order to minimize disturbance of elk and hunters during the hunting season's, visual observations were not attempted. Additionally, VHF collared elk that left the study area or that were on private lands not easily accessible were located opportunistically. Thus, only 50,486 locations were mapped out for

specific locations. However, elk were tracked 1-5 times per week throughout the entire study and in addition to the visual locations and the GPS collar data, an additional 1,251 GMU specific locations were recorded when visuals were unattainable, for a total of 51,737 locations.

Monthly home ranges varied from 42.2 km^2 in June to 70.1 km^2 in October. These dates correspond with the calving season and the rut and firearms hunting season. Seasonal home ranges were similar to what has been found in Wind Cave National Park, 22.9 – 56.0 km^2, (Baumann 1998) and 51.0 km^2 in Custer State Park (Millspaugh 1995). Rice (1988) reported home ranges averaged 23.0 – 77.0 km^2 for elk in the Black Hills. Elk home range sizes vary widely and perhaps have as much to do with the method of analysis as they do with individual variation (Howery et al. 1996, Hayes and Jenkins 1997, Bauman 1998). Elk in this study had the largest home range in October. Rice (1988) suggested that increases in elk movement in the fall was likely due to a shift from summer to winter range, the onset of the rut, and even possibly the avoidance of the increase in human activity associated with hunting. Bauman (1998) also noted an increase in elk home range sizes during the fall.

Benkobi et al. (2005) selected two subsets of elk location data, summer (June to August) and winter (January to March), and compared home ranges to those found by Millspaugh (1995) in CSP and those found by Bauman (1998) in Wind Cave National Park. Benkobi et al. (2005) concluded that the summer home ranges of elk in their study were 2.8 to 4.5 times larger than those in Wind Cave and CSP.

Elk Corridors:

The traditional definition of habitat includes four basic components – food, cover, water, and space (Skovlin et al.1982). Elk have been known to travel vast distances in search of those four basic components. Seventy-three percent of collared elk utilized more than one GMU. Four of the 11 cows (36%) collared along the Tilford area, one GPS and three VHF collared cows, crossed Interstate-90 to the east. The GPS collared cow crossed in mid October and stayed on the east side through the December rifle season. The three VHF collared cows had crossed during the calving season and returned shortly after. Actual GPS locations from the VHF collars could not be acquired due to private ownership of the area east of Interstate-90. These four elk were the only elk located outside of an established GMU.

Bait sites, to facilitate capture, were set up along Hwy 385 near the Custer Crossing Corridor. It is uncertain how much these sites may have influenced elk movement in that area. The area was chosen due to the elk naturally wintering in this location. Perhaps there are numerous factors that determine elk movement: weather, food resources, and hunting pressure may all be components as well as GMU terrain features and size.

The slope and aspect of the Black Hills seems to directly affect elk movements. Avoidance of the steeper areas funneled elk to utilize certain corridors in which to cross from one GMU to another. Elk movements and patterns can create conflicts if elk concentrate on lands that are in private

ownership (Benkobi et al. 2005). There is a substantial amount of private land (12 - 98% depending on GMU) (Table 6) in the Black Hills and much of this land is managed for livestock production. GPS collared elk (n = 17) did have 45% of their locations taken on private land.

With 45% of the locations taken on private land, wildlife managers need to work directly with landowners to ensure all input and opinions are considered for decisions related to elk management. Wildlife managers do have several options to address issues on private lands. These options include: habitat enhancement programs, cable fencing, stack yards, and food plots to name a few.

Table 6. Ownership of lands within elk GMU's in the Black Hills of South Dakota.

Unit	United States Forest Service	Private
1	59%	41%
2	88%	12%
3	44%	56%
4	2%	98%
5	82%	18%
7	60%	40%
9	10%	90%

Elk Mortality:

Road access greatly influences elk vulnerability to hunter harvest and has huge potential to influence herd dynamics (Raedeke et al. 2002). At approximately 2.3 km/km^2, the Black Hills of South Dakota has the highest road density of any National Forest (Benkobi et al. 2005).

Hunter harvest and wounding loss are the major factors of mortality in most elk populations (Peek et al. 1967, Peek 1982, Unsworth et al. 1993). Hunting related mortality was 77% for this study. Hunter harvest may account for 90% of bull elk mortality in areas open to rifle hunting (Raedeke et al. 2002). Unsworth et al. (1993) documented 86% hunting mortality of all radio-marked elk in north-central Idaho. The 33% annual bull mortality rate from this study is slightly less than the 40% found by Unsworth et al. (1993) in Idaho and the 42% found in Utah by Kimball and Wolfe (1974). Cow elk suffered 38% annual mortality in this study which is considerably higher than the 11% observed in Idaho by Unsworth et al. (1993) and the 12% in northern Idaho documented by Leptich and Zager (1991). Rumble (2001) in the Black Hills, reported an average of 34% hunter harvest mortality on bulls and 6% hunter harvest mortality on cows, and an additional 5% natural mortality which was actually a single mountain lion kill (Mark Rumble, personal communication 2010). It should be noted that in the late 1990's, during Rumble's study, the management goal was to increase the elk population in much of the Black Hills. In the mid 2000's, the management direction was to reduce elk populations which may explain the differences in reported mortality rates. Elk populations cannot sustain themselves at current mortality rates found in this study.

Hornocker (1970) found that bulls and calves were more susceptible to mountain lion predation than were cow elk. However, in this study, no radio collared bulls were killed by mountain lions. Nevertheless, seven (11%) of the radio collared cows were killed by mountain lions. Two radio collared cows were

killed by mountain lions in 2007, 0 in 2008, and 5 in 2009. Interestingly, while investigating the area around the killed cows, three out of the seven kill sites also had the calf cached, a common behavior and activity of mountain lions.

The higher bull survival in 2007 compared to bull survival in 2008 and 2009 could possibly be explained by capture methods. The 2007 capture of bulls primarily entailed net-gunning and as such, we were limited to smaller antlered raghorn bulls. However, in 2008 and 2009, bulls were darted and larger antlered bulls were incorporated into the marked sample.

Management objectives need to be determined not only for each GMU, but for the entire Black Hills as a whole. This study has shown that elk are utilizing numerous GMU's. Perhaps wildlife managers need to re-evaluate the necessity of GMU boundaries. Some management alternatives to consider include doing away with unit boundaries altogether and have the Black Hills as one GMU; or maintain the GMU boundaries for cow tags and allow the any tag holders to hunt anywhere in the Black Hills. After all, 83% of the collared bulls were located in multiple GMUs throughout the year. Perhaps, more importantly, 24% of the collared bulls were located in more than one GMU during October. Furthermore, this would compliment the Black Hills deer management. Black Hills buck hunters are allowed to hunt anywhere within the Black Hills and only the anterless hunters are restricted to units. Lastly, looking only at recorded locations, there is an argument for doing away with the Hwy 385 boundary between GMU's 2 & 7. GMU 7 could be incorporated into unit 2. The same

argument could be made for combining GMU's 4, 5, and 9. The collared elk utilized each of the units throughout the year.

Game managers can use these suggestions, data collected from this study, combined with landowner tolerances, hunter harvest success and landscape factors in future management decisions and recommendations to the Commission.

MANAGEMENT IMPLICATIONS

To properly manage the Black Hills elk herd, seasonal movements and cause specific mortality needed to be determined. This study showed that 73% of the collared elk utilized 2 or more GMU's annually. More importantly, between 30 and 38% of the collared elk were in multiple GMUs during the hunting seasons. Annual cow mortality rates were shown to be excessive and will continue to cause population declines. Elk populations cannot sustain the harvest mortality that has been documented in this study.

Management recommendations include: 1) utilize current mortality rates for the population model and adjust permits accordingly; 2) due to the number of elk moving between GMU's, it is essential to look closely at GMU's canopy cover, slope and aspect, forage availability, harvest rates and management objectives to determine if boundaries should be altered; and 3) with 12 - 90% of private land comprising each of the GMUs in the study area, serious consideration of any landowner concerns needs to be addressed. On private lands there are numerous programs, both state and federal, available to partner with landowners to enhance elk habitat or reduce elk damage or at the very least enhance elk habitat on publicly owned lands to redistribute the elk away from privately owned lands.

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APPENDIX

Appendix A. Elk locations acquired from January 2007 – May 2010 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
elk 154010	cow	39		39						
elk 154020	cow	10			6			3	1	
elk 154020b	cow	11			1				10	
elk 154030	bull	41		20	1	4		22		
elk 154040	bull	31		5	1	9		16		
elk 154040b	bull	21		5				16		
elk 154050	cow	14						14		
elk 154050b	cow	17		16		1				
elk 154060	cow	27						27		
elk 154060b	cow	4		2			2			
elk 154070	bull	31		1	6	7		16		
elk 154070b	bull	31		5		2		25		
elk 154080	cow	30			2			28		
elk 154090	cow	40				25		12		
elk 154090b	bull	18		8			10			
elk 154110	cow	84		4		59		18		
elk 154130	cow	40			2	8		18		

Appendix A Continued. Elk locations acquired from January 2007 – May 2010 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
elk 154130b	cow	24			2	1		21		
elk 154140	cow	43			35			2	6	
elk 154150	cow	69		13		36		20		
elk 154160	bull	34		3		16		15		
elk 154160b	bull	36		1		1		34		
elk 154170	bull	66		2	2	8		38	16	
elk 154180	bull	52		22	1	2		27		
elk 154190	cow	79				61	1	17		
elk 154200	cow	30			10			17	2	
elk 154200b	cow	15		6			9			
elk 154210	cow	4						3	1	
elk 154220	cow	55			11			44		
elk 154230	cow	21		21						
elk 154250	cow	17				10			7	
elk 154250b	cow	12			1	9		1	1	
elk 154260	bull	26					26			
elk 154260b	bull	11		1		1		9		

Appendix A Continued. Elk locations acquired from January 2007 – May 2010 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
elk 154260c	bull	5				1	4			
elk 154270	cow	21					21			
elk 154270b	cow	38		1		27		9	1	
elk 154280	cow	12		7			5			
elk 154280b	bull	14		1			13			
elk 154290	cow	21					21			
elk 154290b	cow	14		11		1		2		
elk 154300	cow	59			10	1		45	3	
elk 154310	cow	55		28			27			
elk 154320	cow	19					19			
elk 154320b	cow	28			13			2	13	
elk 154340	cow	29		29						
elk 154350	cow	24		24						
elk 154360	cow	21					21			
elk 154360b	cow	7			3				4	
elk 154370	cow	21		21						
elk 154380	bull	54		2			52			

Appendix A Continued. Elk locations acquired from January 2007 – May 2010 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
elk 154390	bull	22					22			
elk 154390b	bull	11		2			9			
elk 154390c	bull	36				35		1		
elk 154400	bull	18					18			
elk 154420	cow	38			1	6		31		
elk 154430	cow	32					32			
elk 154430b	bull	7					7			
elk 154440	bull	62		7			55			
elk 154450	bull	35		2			33			
elk 154450b	cow	5		5						
elk 154460	bull	13		6			7			
elk 154470	cow	8		5			3			
elk 154480	bull	22			1	1		20		
elk 154500	bull	6		1			5			
elk 154510	cow	10		8			2			
elk 154520	cow	3		3						
elk 154530	cow	8		6			2			

Appendix A Continued. Elk locations acquired from January 2007 – May 2010 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
elk 154550	cow	2					2			
elk 154570	bull	5		2			3			
elk 154650	bull	7		2				5		
elk 155100	cow	5440			132	3567		1740	1	1304
elk 155150	cow	1687	7				1680			502
elk 155200	cow	3409	32				3377			1165
elk 155200b	cow	2197	1		572			1215	409	1750
elk 155260	cow	1454			12			1442		1363
elk 155260b	cow	3368		2556		490		322		281
elk 155300	cow	1653	12				1641			670
elk 155300b	cow	4056		371			3685			27
elk 155350	cow	1239		23			1216			
elk 155350b	cow	3565		3158	28	162		217		200
elk 155400	cow	3708			281	6		3420	1	3339
elk 155400b	cow	2130		2129			1			
elk 155450	cow	2900	2		481	6		2105	306	2156
elk 155500	cow	646					646			284

Appendix A Continued. Elk locations acquired from January 2007 – May 2010 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
elk 155500b	cow	4091		457			3634			29
elk 155533	bull	1264		150			1114			
elk 155550	cow	1349			1009				340	1009
elk 155550b	cow	2582	1244				1338			1552
elk 155563	bull	1146				719		427		315
elk 1st bull	bull	61					61			
elk 1st cow	cow	421		2		293		124	1	57
elk 2nd bull	bull	221		8			213			
elk 385 cow	cow	1299		1159			140			

<> means 'NOT' in any Game Management Unit.
** "Private" is the land east of the BHNF, not the inholdings. An elk can be in Private AND a unit at the same time. Only GPS data was analyzed for locations acquired on private lands.

Appendix B. Elk locations acquired in September 2007 – 2009 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
154030	bull	2		2						
154040b	bull	1						1		
154050	cow	1						1		
154060	cow	2						2		
154070	bull	2			1			1		
154070b	bull	1						1		
154080	cow	1						1		
154090	cow	1				1				
154110	cow	2				2				
154130	cow	2						2		
154150	cow	1				1				
154160	bull	1						1		
154170	bull	2			1			1		
154180	bull	3		2				1		
154190	cow	2				1		1		
154200	cow	2						2		

Appendix B Continued. Elk locations acquired in September 2007 – 2009 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
154220	cow	2			1			1		
154250b	cow	1				1				
154270b	cow	1				1				
154290	cow	1					1			
154300	cow	3			1			2		
154380	bull	1		1						
154480	bull	1						1		
155100	cow	342				342				17
155150	cow	173	1				172			96
155200	cow	328	2				326			90
155200b	cow	176						176		176
155260	cow	176			5			171		176
155260b	cow	353		335		18				14
155300	cow	167					167			99
155300b	cow	340					340			97
155350	cow	103					103			94

Appendix B Continued. Elk locations acquired in September 2007 – 2009 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
155350b	cow	332		332						27
155400	cow	353			5			348		353
155400b	cow	176		176						2
155450	cow	178			5			173		178
155500b	cow	351					351			108
155550	cow	178			177				1	177
155550b	cow	173					173			46
155563	bull	29				25		4		
155533	bull	85		43			42			
385 cow	cow	103		103						

<> means 'NOT' in any Game Management Unit.
** "Private" is the land east of the BHNF, not the inholdings. An elk can be in Private AND a unit at the same time. Only GPS data was analyzed for locations acquired on private lands.

Appendix C. Elk locations acquired in October 2007 – 2009 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
154010	cow	2		2						
154030	bull	1			1					
154040	bull	3			1	2				
154040b	bull	4						4		
154050	cow	3						3		
154060	cow	3						3		
154070	bull	7			3			4		
154080	cow	2			1			1		
154090	cow	6				6				
154090b	bull	1					1			
154110	cow	6				6				
154130	cow	4			1			3		
154130b	cow	3						3		
154140	cow	3			3					
154150	cow	5				3		2		
154160	bull	2				1		1		

Appendix C Continued. Elk locations acquired in October 2007 – 2009 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
154160b	bull	3						3		
154170	bull	1							1	
154180	bull	3			1			3		
154190	cow	8				8				
154200	cow	3			1			2		
154200b	cow	2					2			
154220	cow	5			1			4		
154230	cow	2		2						
154250	cow	5				3	2			
154260	bull	2					2			
154260c	bull	1					1			
154270	cow	2					2			
154270b	cow	4				4				
154290	cow	2					2			
154290b	cow	2			1			1		
154300	cow	5			2			3		

Appendix C Continued. Elk locations acquired in October 2007 – 2009 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
154310	cow	5		4			1			
154320	cow	3			1		2			
154340	cow	2		2						
154350	cow	1		1						
154360	cow	2					2			
154370	cow	2		2						
154380	bull	2		1			1			
154390	bull	2					2			
154390c	bull	6				5		1		
154420	cow	1						1		
154440	bull	3		2			1			
154450	bull	1					1			
154460	bull	1		1						
154470	cow	1		1						
154480	bull	2			1			1		
154500	bull	1		1						

Appendix C Continued. Elk locations acquired in October 2007 – 2009 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
154510	cow	1		1						
154530	cow	1		1						
154570	bull	1		1						
154650	bull	1						1		
155100	cow	365				346		19		121
155150	cow	181					181			71
155200	cow	178					178			62
155200b	cow	184			17			167		184
155260	cow	120			6			114		120
155260b	cow	353		239		114				32
155300	cow	179					179			60
155300b	cow	354		46			308			84
155350b	cow	364		364						131
155400	cow	280			86			194		276
155400b	cow	179		179						36
155450	cow	167			6			161		167

Appendix C Continued. Elk locations acquired in October 2007 – 2009 in the Black Hills of South Dakota.

Elk	sex	Total	<>	2	4	5	7	9	CSP	Private
155500b	cow	349		81			268			69
155550	cow	4			4					4
155550b	cow	182	72				110			133
155563	bull	13				13				
385 cow	cow	61		61						

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Appendix D. Elk locations acquired 1 - 15 December 2007 – 2009 in the Black Hills of South Dakota.

Elk	Sex	Total	<>	2	4	5	7	9	CSP	Private
154010	cow	1		1						
154030	bull	4						4	1	
154040	bull	2						2		
154060	cow	3						3		
154070	bull	2			1			1		
154070b	bull	7						7	1	
154080	cow	2						2		
154090	cow	2						2		
154090b	bull	1					1			
154110	cow	7				4		3		
154130	cow	2						2		
154130b	cow	5						5	2	
154140	cow	6			6				1	
154150	cow	7				5		2		
154160	bull	2						2		
154160b	bull	5						5	1	
154170	bull	3			1			2		

Appendix D Continued. Elk locations acquired 1 - 15 December 2007 – 2009 in the Black Hills of South Dakota.

Elk	Sex	Total	<>	2	4	5	7	9	CSP	Private
154180	bull	3						3		
154190	cow	9				4		5		
154200	cow	3						3		
154200b	cow	1		1						
154220	cow	7						7	2	
154250	cow	2				2				
154250b	cow	2				2				
154260b	bull	2				2				
154270	cow	1					1		1	
154270b	cow	3		1		2				
154280	bull	1					1			
154290	cow	2					2			
154300	cow	6						4	2	
154310	cow	6		3			3			
154320	cow	2			1				2	
154320b	cow	2			2					
154340	cow	1		1						

Appendix D Continued. Elk locations acquired 1 - 15 December 2007 – 2009 in the Black Hills of South Dakota.

Elk	Sex	Total	<>	2	4	5	7	9	CSP	Private
154350	cow	2		1	1					
154360	cow	1					1			
154380	bull	4					4			
154390c	bull	1				1				
154420	cow	4						4		
154430	bull	2					2			
154440	bull	4					4			
154450	bull	3		1			2			
154470	cow	2		2						
154480	bull	4						4	2	
155100	cow	180			6	132		42		79
155150	cow	17					17			10
155200	cow	88	2				86			64
155200b	cow	90						90		90
155260b	cow	89		89						5
155300	cow	12					12			12
155300b	cow	177		39			138			52

Appendix D Continued. Elk locations acquired 1 - 15 December 2007 – 2009 in the Black Hills of South Dakota.

Elk	Sex	Total	<>	2	4	5	7	9	CSP	Private
155350b	cow	171		171						30
155400	cow	90						90		14
155400b	cow	90		90						
155450	cow	90						90		90
155500b	cow	179		40			139			52
155550b	cow	89	89							89
385 cow	cow	18		18						

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Appendix E. Cow elk locations acquired the last week of May and the first week of June 2007 – 2009 in the Black Hills of South Dakota.

Elk	Total	<>	2	4	5	7	9	CSP	Private
154010	8		8						
154020	2			2					
154020b	1							1	
154030	8		6		2				
154050	5		1				4		
154050b	4		4						
154060	4						4		
154060b	1					1			
154080	4						4		
154090	7				3		4		
154110	7		1		3		3		
154130	7				2		5		
154130b	1						1		
154140	5			5					
154150	4		3				1		
154190	7				2		5		

Appendix E Continued. Cow elk locations acquired the last week of May and the first week of June 2007 – 2009 in the Black Hills of South Dakota.

Elk	Total	<>	2	4	5	7	9	CSP	Private
154200	3			1			2		
154200b	1					1			
154220	5			1			4		
154230	5		5						
154250	5					5			
154250b	2							2	
154270	5					5			
154270b	3						3		
154280	2					2			
154290	5					5			
154290b	4		4						
154300	5			1			4		
154310	9		5			4			
154320	4					4			
154320b	3						1	2	
154340	5		5						

Appendix E Continued. Cow elk locations acquired the last week of May and the first week of June 2007 – 2009 in the Black Hills of South Dakota.

Elk	Total	<>	2	4	5	7	9	CSP	Private
154350	5		5						
154360	4					4			
154370	6		6						
154420	4						4		
155100	240				219		21		
155150	84					84			
155200	163					163			8
155200b	84			10			74		84
155260	82						82		43
155260b	155		50		90		15		14
155300	82					82			82
155300b	163					163			
155350	82					82			
155350b	166		108		58				
155400	167						167		79
155400b	80		80						

Appendix E Continued. Cow elk locations acquired the last week of May and the first week of June 2007 – 2009 in the Black Hills of South Dakota.

Elk	Total	<>	2	4	5	7	9	CSP	Private
155450	154						154		82
155500	75					75			
155500b	158					158			
155550	84			84					84
155550b	161					161			4
385 cow	86		86						

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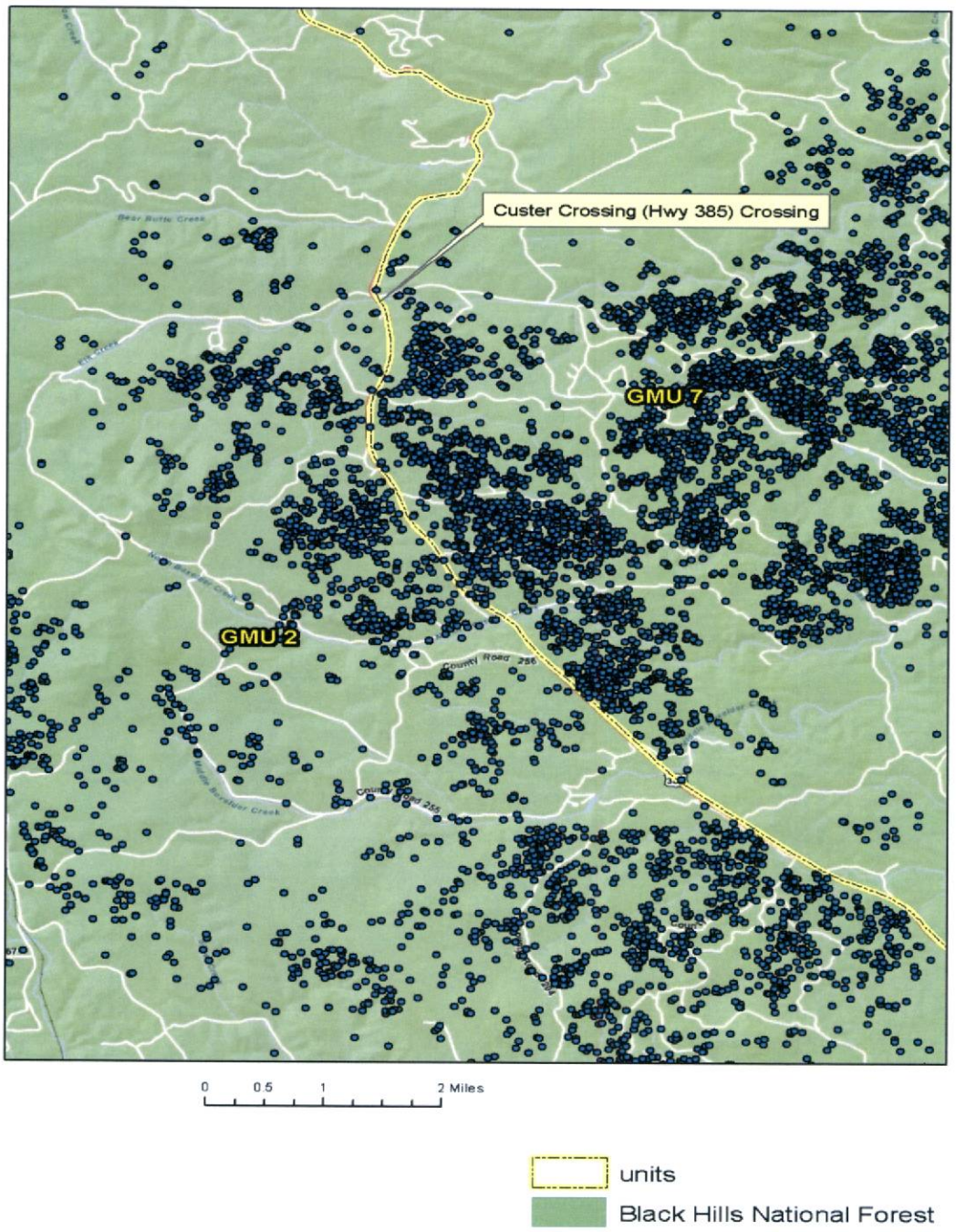
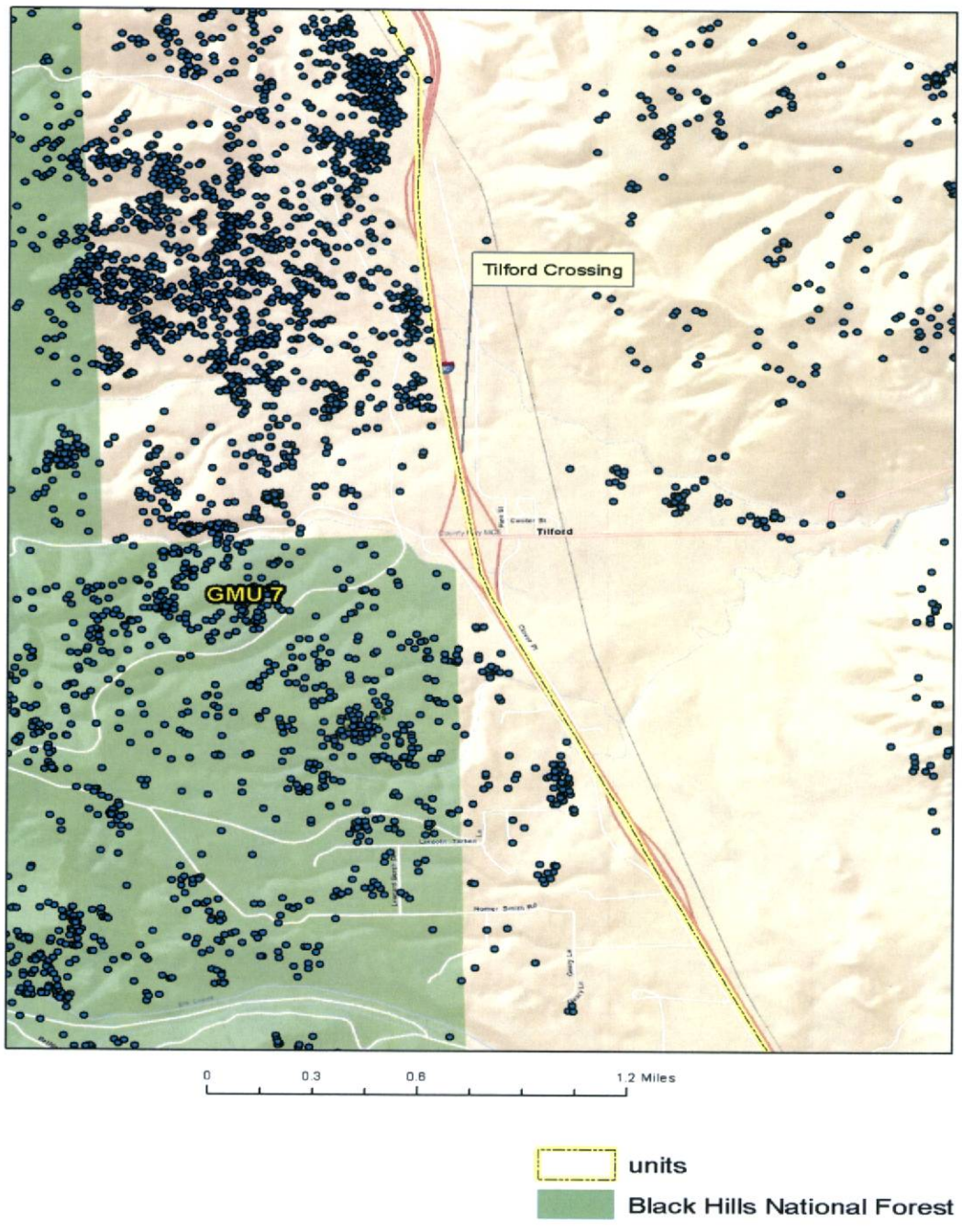
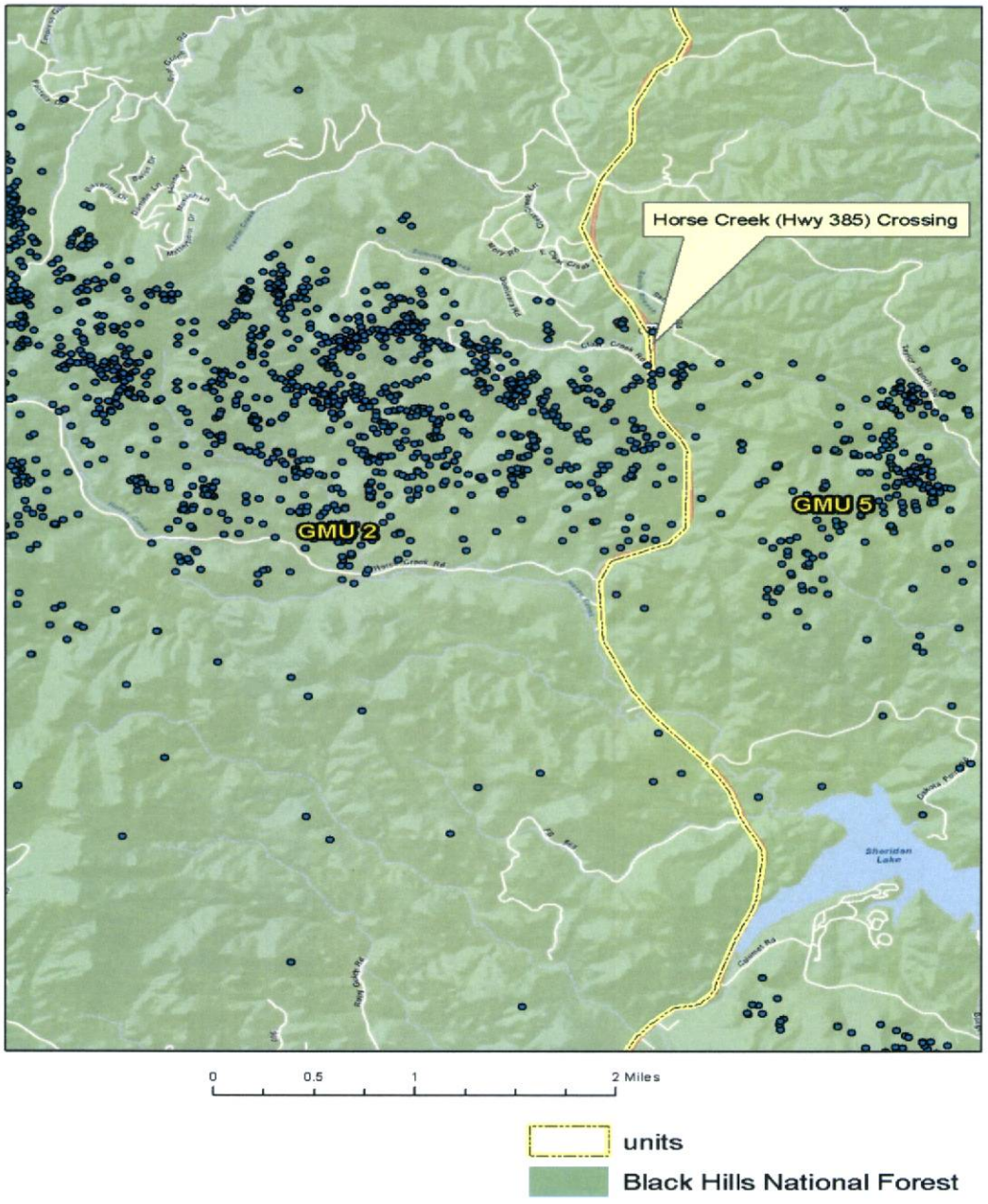


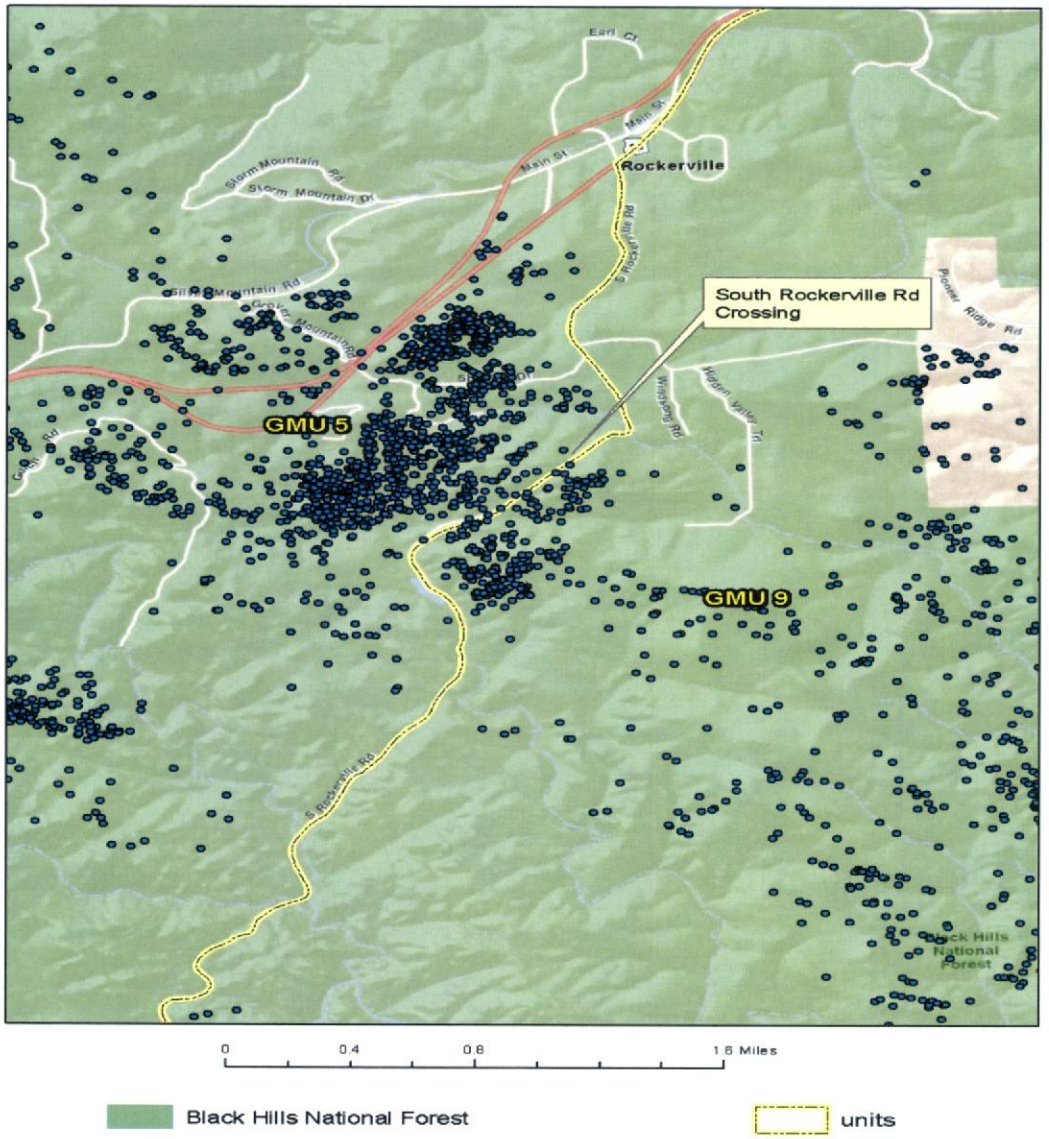
Appendix F. Close up of the Custer Crossing Corridor in the Black Hills of South Dakota, 2007-2010.



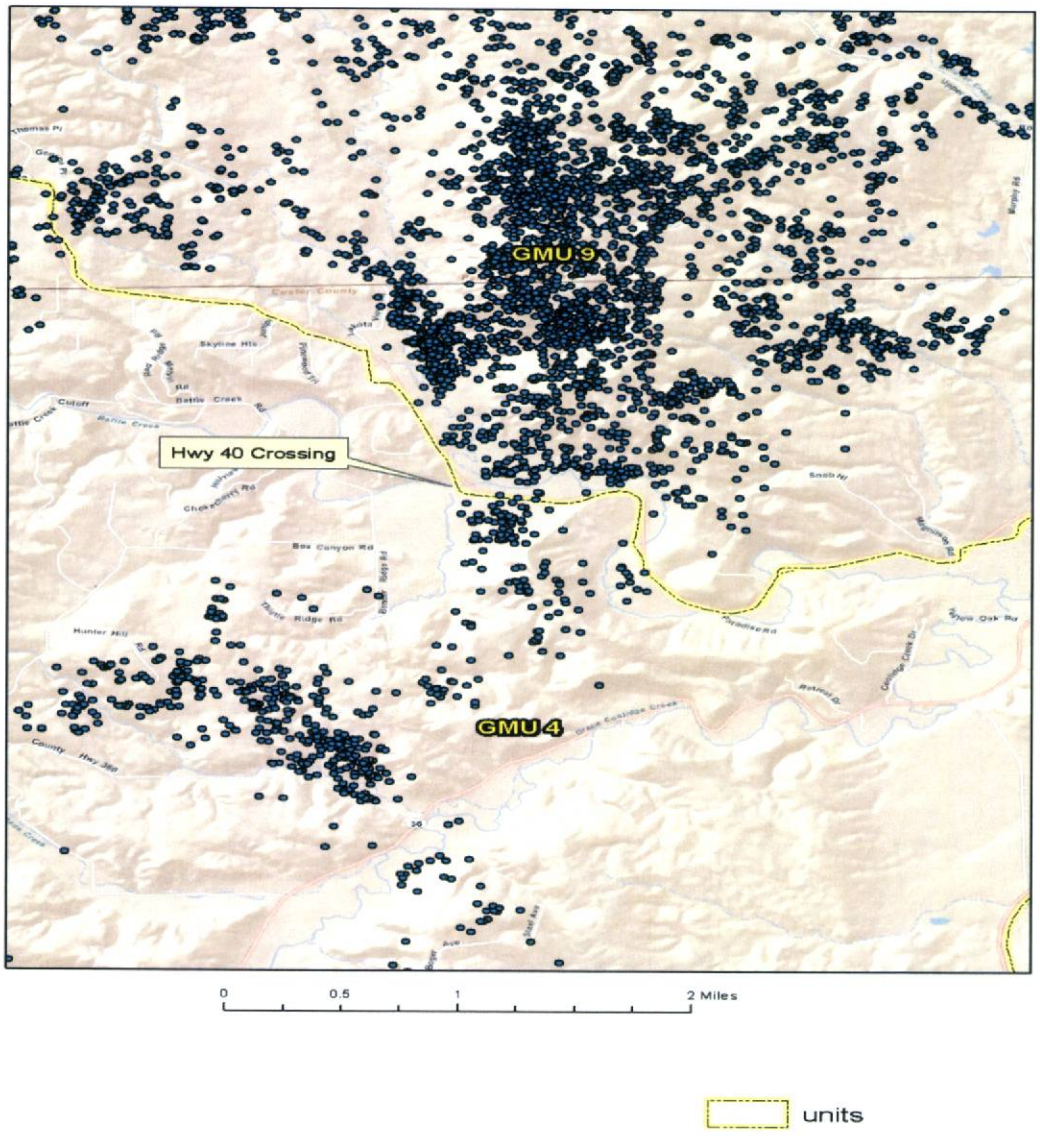
Appendix G. Close up of the Tilford Crossing Corridor in the Black Hills of South Dakota, 2007-2010.



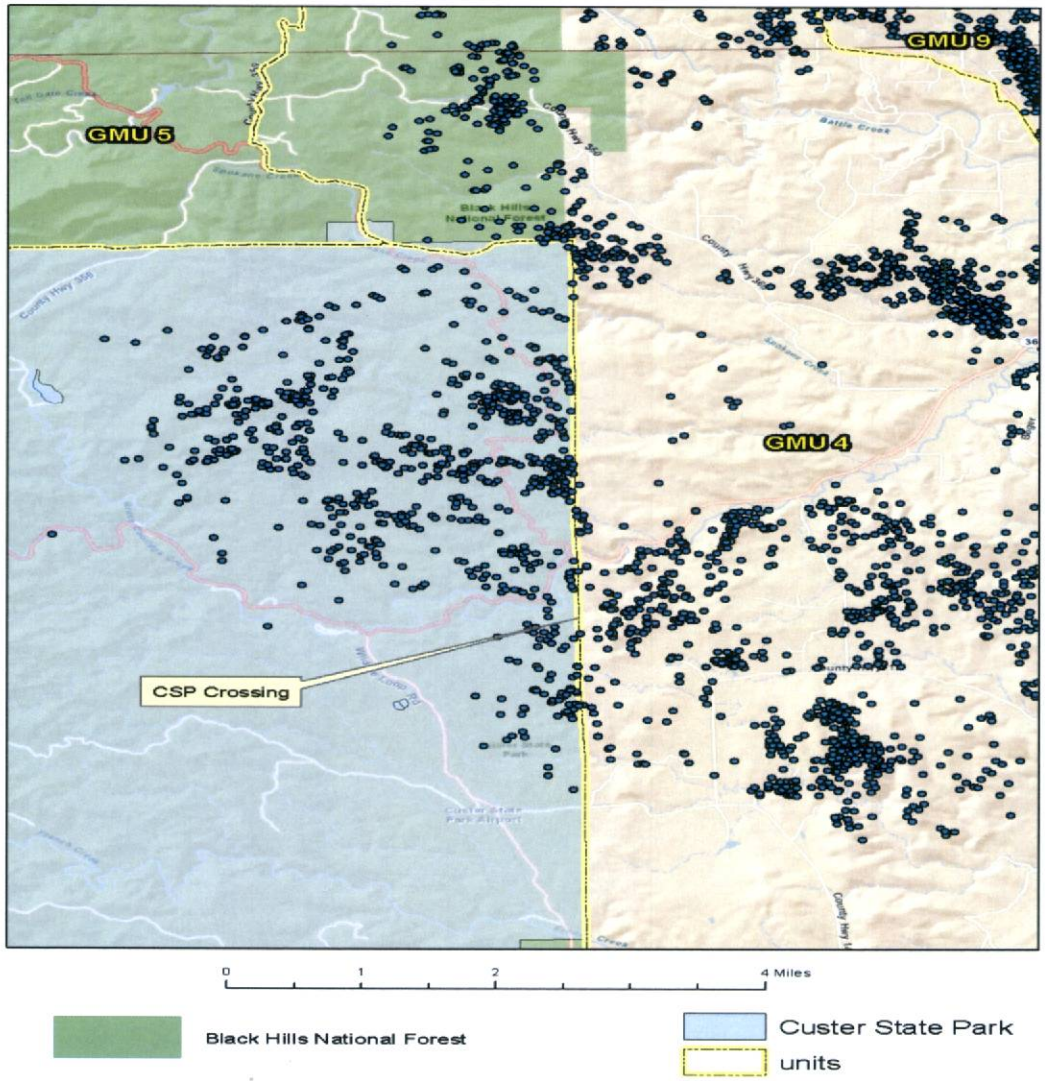
Appendix H. Close up of the Horse Creek Crossing Corridor in the Black Hills of South Dakota, 2007-2010.



Appendix I. Close up of the South Rockerville Rd Crossing Corridor in the Black Hills of South Dakota, 2007-2010.



Appendix J. Close up of the Hwy 40 Crossing Corridor in the Black Hills of South Dakota, 2007-2010.



Appendix K. Close up of the Custer State Park Crossing Corridor in the Black Hills of South Dakota, 2007-2010.