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Status, Distribution, and Density of White-tailed Jackrabbits and Black-tailed Jackrabbits in South Dakota

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STATUS, DISTRIBUTION, AND DENSITY OF WHITE-TAILED JACKRABBITS AND BLACK-TAILED JACKRABBITS IN SOUTH DAKOTA

By

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

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This thesis and all the work that was put forth is dedicated to the loving memory of Theodore Hirning. – "Jackrabbits are one of the most peaceful animals in nature."

ABSTRACT

STATUS, DISTRIBUTION, AND DENSITY OF THE WHITE-TAILED JACKRABBIT AND BLACK-TAILED JACKRABBIT IN SOUTH DAKOTA

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The status of jackrabbit (*Lepus* spp.) populations throughout the Northern Great Plains has been a cause for concern by wildlife managers in recent years and there has been a paucity of information about the ecology of the white-tailed jackrabbit (*Lepus townsendii*) and the black-tailed jackrabbit (*Lepus californicus*) in South Dakota. Since there have been little monitoring efforts for hares, 21 permanent spotlight line transects were established across South Dakota for future surveying efforts. These transects were surveyed to obtain baseline information about jackrabbit density and distribution throughout the state. Jackrabbit density was highest in the northwestern portions of the state and lowest in east central South Dakota. The white-tailed jackrabbit was observed throughout the state, but the black-tailed jackrabbit was only confirmed in south central South Dakota.

The reproductive biology of white-tailed jackrabbits was evaluated from 314 animals collected in 44 counties throughout South Dakota from June 2004 to September 2005. Jackrabbits were classified into three age classes based on the closure of the proximal epiphysis of the humerus using x-ray analysis. Fluctuations occurred in

measured weights of reproductive organs for both sexes which were used to determine annual reproductive activity. The 2005 breeding season began in late February and proceeded until mid July, approximately 142 days, allowing for females to potentially produce 3.3 litters. Breeding synchrony was apparent throughout the breeding season which was determined from the overlap of four periods of estimated conception and parturition dates. Litter size ranged from one to eight, with an average of 4.6 per female. Prenatal mortality from pre-implantation and post-implantation loss was observed to be greatest (32%) in the first littering period in 2005.

Capture methods and home range size of white-tailed jackrabbits has received little attention in the literature and has not been reported in South Dakota. We used live traps and a drive corral to compare capture rates of jackrabbits in three selected fields in Brookings, Kingsbury, and Beadle Counties in eastern South Dakota. The Kingsbury and Beadle sites were primarily grazed pastures while the Brookings telemetry site was largely composed of cultivated land. There were 18 white-tailed jackrabbits captured using live traps with an additional 16 captured using the drive corral. We averaged 0.04 jackrabbits per trap night and 0.29 jackrabbits per man-hour using live traps. Using the drive corral, we averaged 1.23 jackrabbits per trap attempt and 0.48 jackrabbits per man-hour. The fixed kernel estimator was used to calculate home range size for 25 jackrabbits which ranged from $0.40km^2$ to $4.76km^2$. Average female home range size ($1.09km^2$) did not significantly differ from average male home range size ($1.34km^2$).

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Chapter 1. Introduction

Jackrabbits (*Lepus* spp.) are a common species on the prairie landscape and an important species in prairie food webs. Management practices that affect hare populations may affect other important species such as mammalian and avian predators (Plettner 1984). Jackrabbits have also historically served as an important game species for hunters. While it has been suggested that *Lepus* spp. have cyclic populations (Rowman and Keith 1956, Donoho 1972, Gross et al. 1974, Nowak and Paradiso 1983, Anderson and Shumar 1986), there is concern that there has been a general downward trend in jackrabbit populations in the Northern Great Plains. Two species inhabit South Dakota, the white-tailed jackrabbit (*Lepus townsendii*) and the black-tailed jackrabbit (*Lepus californicus*).

Jackrabbits are taxonomically classified as hares since the young are precocial when born. The large feet and ears, the presence of a supraorbital process on the frontal bone, and a straight cutting edge on the upper incisor are characteristics of jackrabbits that place them in the family Leporidae (Dunn et al. 1982). Jackrabbits use speed, cryptic coloration, and their senses of smell, sight, and hearing to detect and avoid predators (Higgins et al. 2000). Jackrabbits utilize forms, shallow depressions usually adjacent to vegetation (Vorhies and Taylor 1933), during the day and they actively forage at night. Form location is a crucial habitat characteristic for leporids, providing security from predators, inclement weather, and a place to conserve metabolic energy or reduce heat load (Althoff et al. 1997, Brown and Krausman 2003). Leporids are mostly nocturnal and somewhat crepuscular, with seasonal variations in activity patterns (Knowlton et al.

1968; Lemnell and Lindlof 1981; Mech et al. 1966; Rogowitz 1997). Jackrabbits tend to respond to seasonal environmental fluctuations by alternately concentrating and dispersing within a given range (Donoho 1972).

White-tailed jackrabbits range from south central British Columbia and east central California to central Manitoba and northern Missouri (Nowak and Paradiso 1983) and as far south as northern portions of New Mexico and Arizona (Dunn et al. 1982). The white-tailed jackrabbit occupies a variety of habitats but tends to avoid forests and woodlands, which may indicate a selection for areas with good visibility and fast escape routes (Higgins et al. 2000). In addition, some researchers believe that white-tailed jackrabbits are less adapted to cultivated areas than black-tailed jackrabbits (Hansen and Flinders 1969, Dunn et al. 1982, Jones et al. 1985). Sexual dimorphism has been documented in white-tailed jackrabbits, with females being greater in length and weight than males (Dunn et al. 1982). White-tailed jackrabbits exhibit two distinct coats, which include a grayish brown in summer and white in winter.

Black-tailed jackrabbits occupy open, short-grass prairies with scattered shrubs, yucca (*Yucca* spp.), or cacti in semiarid climates (Higgins et al. 2000). The black-tailed jackrabbit is the most common jackrabbit in the western United States ranging from Iowa to the Pacific Coast and south to northern Mexico (Lechleitner 1958, Dunn et al. 1982). This species is slightly smaller than the white-tailed jackrabbit, with a characteristic black dorsal strip extending along the back and onto the tail (Dunn et al. 1982, Jones et al. 1985).

Leporids are entirely herbivorous and several species, including white-tailed jackrabbits and black-tailed jackrabbits, exhibit coprophagy. Hansen and Flinders (1969) report that fecal pellets contain high levels of protein and B vitamins which are produced by intestinal bacteria. Black-tailed jackrabbits are known to prefer succulent green vegetation when available, however food habit studies have shown high variability among regions (Dunn et al. 1982). The diet of black-tailed jackrabbits primarily consists of grasses and forbs during summer months and changes to shrubs during winter months when succulent herbs become unavailable (Hansen and Flinders 1969). White-tailed jackrabbits tend to forage on vegetation that is in the pre-reproductive or early reproductive stages of development (Flinders and Hansen 1972), and have seasonal dietary fluctuations similar to black-tailed jackrabbits (Higgins et al. 2000).

The gradual movement of black-tailed jackrabbits into areas previously occupied by white-tailed jackrabbits has been documented in certain regions of their distribution. Habitat selection may promote or limit some of these movements with varying land use practices. Brown (1947) attributed the conversion of open prairie to cultivated land as the most reasonable explanation for the reduction of white-tailed jackrabbit populations and subsequent increase in black-tailed jackrabbit populations in Kansas. Watkins and Nowak (1973) speculated that the decline of white-tailed jackrabbits in Missouri resulted from over-harvesting and loss of habitat. Flinders and Hansen (1975) reported that white-tailed jackrabbits selected upland habitats that were more sparsely vegetated than lowland habitats preferred by black-tailed jackrabbits. Black-tailed jackrabbits are more efficient in utilizing a feeding site than white-tailed jackrabbits (Dunn et al. 1982), which may allow them to displace white-tailed jackrabbits due to their greater adaptability (Hansen and Flinders 1969).

Fluctuations in jackrabbit population density tend to occur on a cyclic basis; however, a definitive explanation for these fluctuations is lacking. Nowak and Paradiso (1983) suggested a possible reason for the cycle might be a response to low winter food supply and elevated predator populations. Fertility and carrying capacity may also play a role in these fluctuations. In southeastern Idaho, French et al. (1965) found that as the jackrabbit population increased, the length of their breeding season decreased and reproductive output declined.

Jackrabbits are a desirable species in prairie landscapes, providing sport hunting and an aesthetic value if not too numerous (Dunn et al. 1982). The introduction of agriculture into jackrabbit habitats apparently triggered an enormous surge in lagomorph populations (Marsh and Salmon 1981). Jackrabbits became a nuisance and were controlled in the late 1800's usually with large rabbit drives (Palmer 1896). A rabbit drive, often thought of as a special event, would consist of several farmers that would drive rabbits toward a central corral where they would kill the rabbits by the hundreds (Dunn et al. 1982). The largest recorded rabbit drive involved approximately 8,000 people where 20,000 to 30,000 jackrabbits were killed (Palmer 1896).

Objectives

The purpose of this research was to provide data on several aspects of jackrabbit ecology including baseline information regarding the status, distribution, and density of jackrabbit populations in South Dakota. The objectives of this study were to: (1) conduct baseline surveys on white-tailed and black-tailed jackrabbit populations in South Dakota; (2) determine recommended methods for long-term population monitoring of white-tailed and black-tailed jackrabbit populations in South Dakota; (3) determine sex and age ratios and reproductive potential in white-tailed jackrabbits in South Dakota; and (4) assess capture methods, home range, and causes of mortality of white-tailed jackrabbits in eastern South Dakota.

Since several questions have arisen about jackrabbit populations in the Northern Great Plains, this study was designed to increase our fundamental knowledge about these species in South Dakota. This research will help wildlife biologists monitor South Dakota's jackrabbit populations, understand management needs, and recommend additional studies concerning jackrabbit ecology in South Dakota. In addition, the information obtained will assist wildlife managers by providing methods for long-term jackrabbit population monitoring which may be crucial during population fluctuations.

Study Area

Jackrabbits were surveyed throughout South Dakota except for the Black Hills. The state encompasses 201,022 square kilometers (77,615 square miles) or approximately 20.2 million ha (50 million acres) (Visher 1918). States bordering South Dakota include Minnesota and Iowa to the east, Nebraska to the south, Wyoming and Montana to the west, and North Dakota to the north. The eastern portion of the state lies within the Prairie Plains, which was created through glaciation and is characterized by low hills, marshes and lakes (Visher 1918). Most of the western portion of the state lies within the Great Plains, which includes a more rugged landscape of rolling hills. Also in western

South Dakota are the Badlands, as well as the Black Hills, an outpost of the Rocky Mountains. The Black Hills region was not surveyed since forested areas are not characteristic jackrabbit habitat. Since the Missouri river essentially divides the state, the western half is referred to as West River South Dakota and the eastern half as East River South Dakota. There are 66 counties within South Dakota, 22 located in West River South Dakota and 44 located in East River South Dakota.

South Dakota lies within a latitude of 43° to 46° and its position in the continental interior relates to hot summers and cold winters (Visher 1918). Northwest winds prevail during colder months while southeast winds dominate during warmer months. The mean annual temperature of the state is approximately 7.2°C, but eastern South Dakota averages 6.9°C while western South Dakota averages 7.6°C (Visher 1918). Western South Dakota is generally warmer and northern counties differ in mean annual temperature by approximately 2°C from southern counties (Hogan and Fouberg 1998). The northeast quarter of South Dakota tends to be the coldest and the southwestern portions the warmest (Visher 1918). The growing season generally averages 130 days (Visher 1918).

Annual precipitation averages approximately 50.8 cm for the state, with eastern South Dakota receiving more precipitation than western South Dakota (Visher 1918). The amount of rainfall throughout South Dakota decreases toward the west and north.

Tall-grass prairie dominates much of the area in eastern South Dakota and makes a transition to northern mixed grass prairie to the west. Dominating grasses include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass

(*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), wheatgrass (*Agropyron* spp.), prairie dropseed (*Sporobolus heterolepis*), tall dropseed (*Sporobolus asper*), green needlegrass (*Stipa viridula),* porcupine grass (*Stipa spartea*) (Johnson and Nichols 1982). Examples of common forbs include milkvetch (*Astragalus* spp.), white prairie clover (*Dalea candida*), purple prairie clover (*Dalea purpurea*), and American licorice (*Glycyrrhiza lepidota*) (Johnson and Nichols 1982). In the northwest and southwest portions of South Dakota, natural vegetation includes silver sagebrush (*Artemisia cana*), big sagebrush (*Artemisia tridentata),* blue grama (*Bouteloua gracilis)* and buffalograss (*Buchloe dactyloides)* (Bryce et al. 1998).

Land use is typically for agricultural purposes especially in East River South Dakota. Agriculture is the most important aspect of the economy in the area (Hogan and Fouberg 1998). The most commonly cultivated crops include corn (*Zea* spp.), soybeans (*Glycine max*), alfalfa (*Medicago sativa*), and several small grains including oats (*Avena sativa*), wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*). Livestock production is also prevalent throughout South Dakota and mostly includes dairy and beef cattle and sheep.

CHAPTER 2. DISTRIBUTION, DENSITY, AND PERMANENT MONITORING ROUTES OF JACKRABBITS IN SOUTH DAKOTA

INTRODUCTION

Density estimates are difficult to obtain for jackrabbits since they tend to concentrate in some locations and are absent from others (French et al. 1965). Abundance data for jackrabbits may provide wildlife managers with a means to determine crop or range depredations as well as an understanding of predator-prey relationships (Smith and Nydegger 1985, Wywialowski and Stoddart 1988). Jackrabbit habitat selection varies seasonally as well as diurnally, rendering most census methods to be unreliable (French et al. 1965). Young leporids are not easily censused by any method due to their secretive behavior (Flinders and Hansen 1973). Historic survey methods for jackrabbits have included roadside counts (Vorhies and Taylor 1933, Stoddart 1972, Medlin 1974, Fagerstone et al. 1980), walking line transects (Stoddart 1972, Gross et al. 1974, Wywialowski and Stoddart 1988), drive counts (Donoho 1972, Gross et al. 1974), strip transects (Lechleitner 1958, French et al. 1965, Tiemeier 1965, Flinders and Hansen 1973), linear horseback transects (Wywialowski and Stoddart 1988), a mail survey (Majors et al. 1996), road kill counts (Adams and Adams 1959) and spotlight line transects (Smith and Nydegger 1985).

Fluctuations in population densities and shifts in distribution are commonly reported for jackrabbits throughout their range (Dunn et al. 1982). In Kansas, the change in distribution of both the black-tailed jackrabbit and white-tailed jackrabbit was gradual and was attributed to the transformation of prairie to cultivated land which was more favorable for the black-tailed jackrabbit (Brown 1947). A decline of white-tailed jackrabbits in Missouri was thought to be associated with a shift in its range that has been occurring across central North America (Watkins and Nowak 1973). The disappearance of white-tailed jackrabbits in southern Nebraska and consistent abundance in northern portions of the state suggest a northward shift of the species, which may be attributed to a warming trend in North America (Jones 1964).

Factors such as temperature, changes in vegetation, and moisture may influence distribution and density of white-tailed jackrabbits (Watkins and Nowak 1973). White-tailed jackrabbit populations may be affected by high soil moisture content and tall-grass cover, which can be limiting factors in some regions (Bowles 1971). A white-tailed jackrabbit population decline was observed during wet growing seasons in Iowa (Kline 1963).

Several investigators have reported cyclic fluctuations in population densities of jackrabbits. In California, black-tailed jackrabbit populations were reported to reach peak densities every six to 10 years (Evans et al. 1970), and Clark (1975) reported this occurrence every five to 10 years. Black-tailed jackrabbits did not exhibit a cyclic population density in Kansas but dry years yielded higher concentrations of jackrabbits in cultivated fields (Bronson and Tiemeier 1958). In Colorado, Donoho (1972) observed that black-tailed jackrabbits demonstrated a more distinct fluctuation in density than white-tailed jackrabbits.

In order to evaluate jackrabbit populations, several researchers have employed spotlighting techniques between dusk and dawn to increase reliability of results (Donoho 1972, Flinders and Hansen 1973, Plettner 1984, Smith and Nydegger 1985, Rogowitz and Wolfe 1991, Knick and Dyer 1997). Flinders and Hansen (1973) report that leporids are more easily censused on short-grass prairie during the night for several reasons. First, jackrabbits are more active at night when they are foraging (Lechleitner 1958, Tiemeier 1965). Second, the preference for sparse vegetative cover for foraging may make them more visible. Third, their eyes reflect light from the spotlight which may allow observers to identify them in areas where they were less conspicuous during the day (Flinders and Hansen 1973).

Currently, the population status and distribution of white-tailed jackrabbits and black-tailed jackrabbits in South Dakota are unclear. White-tailed jackrabbits were estimated to have a statewide distribution in South Dakota while records indicate that black-tailed jackrabbits are limited to the south central and southwestern portions of the state (Higgins et al. 2000). Anecdotal reports suggest a population decline in South Dakota since 1991.

OBJECTIVES

There has been no research conducted on hares in South Dakota to determine statewide distribution and density. Jackrabbits were spotlighted between dusk and dawn to: (1) provide data about statewide distribution and density estimates of black-tailed and white-tailed jackrabbits; (2) characterize habitat selection of jackrabbits in South Dakota; and (3) establish permanent survey routes for future South Dakota jackrabbit population monitoring. This information may be valuable for researchers to evaluate long-term population trends of hares as well as predator-prey relationships across South Dakota.

METHODS

Transect Design

Stratified random sampling was used to create 21 permanent roadside spotlight transects across the state. Starting points, designated by an intersection, were randomly selected within systematically selected counties. Each transect consisted of improved gravel roads although some transects were designed with short distances of paved roads to ensure continuity. Selected roads were essentially straight with reasonable visibility (>100 yards) on both sides as suggested by Flinders and Hansen (1973).

I selected 10 transects within the East River study area and 11 transects within the West River study area. All East River transects were 64.4 km (40 miles) in length while West River transects were a minimum of 64.4 km in length. Some were slightly longer depending on road availability as well as intersections to serve as permanent start and end points. A transect length of 64.4 km was determined as a feasible distance observers could survey without becoming fatigued, while allowing for the opportunity to survey various habitat types. Transect length was not created in proportion to vegetative occurrence (Anderson et al. 1979, Burnham et al. 1980) due to logistical problems (Smith and Nydegger 1985).

Spotlight Equipment and Survey Procedures

Spotlighting was conducted using two roof-mounted 12-volt spotlights (one million candlepower) manufactured by Lightforce, Inc. (Orofino, ID). Surveys began approximately one hour after sunset and were performed on nights with dry, calm weather. The driver and passenger used spotlights, while a third person recorded data. We spotlighted both sides of the road using a 180 degree pattern from both sides of the truck while the third person focused on spotting hares on the road. Vehicle speed ranged from 10-20 mph depending on vegetative cover in adjacent fields (Smith and Nydegger 1985).

Species confirmation was aided by binoculars and was based on physical traits. For animals that remained stationary, a rangefinder was used to acquire its perpendicular distance from the transect. For each hare that moved after sighting, the perpendicular distance was measured from the area of origination. Habitat type was recorded where each hare was observed. In addition, each point where jackrabbits were sighted along the transect was recorded with a GPS unit.

Surveys were completed once in the fall (Oct-Nov) and once in the spring (Mar-Apr). Due to the survey timeline and cost effectiveness, individual surveys were not replicated within seasons. Overall, the 10 East River transects were surveyed four times, once during spring and fall, 2004 and 2005. West River transects were surveyed three times, once during fall of 2004 and 2005, and spring of 2005.

Distance Sampling Assumptions and Analysis

Distance sampling techniques were used to calculate density estimates for each transect. There are four basic assumptions for density estimation from line transect sampling (Burnham et al. 1980): (1) animals on the center line of the transect are never missed (sighting probability of 1.0); (2) animals do not move prior to sighting and are only counted once; (3) perpendicular distances are accurately measured; (4) sightings are independent. In addition, Flinders and Hansen (1973) report assumptions when using roads as transects which include: (1) the transects are representative of the area being sampled; (2) the truck and spotlight do not cause the jackrabbits to move prior to being spotted; (3) mean estimates of density are valid; and (4) roadways do not affect animal distribution within the study area.

All data were analyzed using program DISTANCE to provide unbiased estimates of density. After inspection of the data, I elected to use the Fourier Series Estimator, which has been shown to perform well in a variety of situations (Burnham et al. 1980, Buckland et al. 1993). Some data sets did not adhere to a monotonically decreasing histogram (as distance increases, observations decrease) but I observed the lowest coefficients of variation and AIC values using the Fourier Series Estimator. All analyses were executed on untruncated and/or ungrouped distributions. I did not need to eliminate any observations as there were no extreme outliers. Density estimates were calculated for each seasonal survey of individual transects and a mean density estimate was calculated for all surveys among transects for baseline information about jackrabbit density.

Habitat Availability and Selection Analysis

During the fall 2005 survey, habitat availability of individual transects were determined from 0.80 km (0.5 mile) point estimates. Habitat type was recorded on both sides of the road and tallied to determine percent availability. Habitat types were classified into grassland or agricultural land. Since agricultural land is rarely converted back to grassland, variation among years in crop types planted within the same fields was ignored. The availability data were then used to determine nocturnal or foraging habitat selection of jackrabbits using chi-square analysis ($\alpha = 0.05$, critical value 3.84).

RESULTS

East River Transects

White-tailed jackrabbits were observed on all transects throughout eastern South Dakota. Black-tailed jackrabbits were not observed on any East River transect surveyed throughout the study period. Transects were named after counties in which they lay; however they were also numbered in descending order from highest to lowest average jackrabbit density estimate. Maps of each transect can be found in Appendix I.

Beadle, Miner, Sanborn (Transect # 1)

The average number of white-tailed jackrabbits observed was 65 and numbers ranged from 51 to 77. The average density estimate was 4.60/km^2 with a range from 2.73/km^2 to 7.59/km^2 (Table 1*a*). Habitat availability was estimated to be 31% cultivated land and 69% grassland. Selection of agricultural habitat was observed in three surveys with random use observed in the fourth survey (Table 1*b*).

Brown, Spink (Transect # 2)

The average number of white-tailed jackrabbits observed was 46.5 and numbers ranged from 24 to 68. The average density estimate was 2.99/km^2 with a range from 2.11/km^2 to 4.10/km^2 (Table 2*a*). Habitat availability was estimated to be 98% cultivated land and 2% grassland. Jackrabbits appeared to select grassland during three surveys while random use was concluded for the fourth survey (Table 2*b*).

Day, Marshall (Transect # 3)

The average number of white-tailed jackrabbits observed was 24.5 and numbers ranged from 13 to 30. The average density estimate was 2.30/km^2 with a range from 0.74/km^2 to 5.18 km^2 (Table 3*a*). Habitat availability was estimated to be 68% cultivated land and 32% grassland. Habitat selection varied among surveys (Table 3*b*).

Jerauld, Aurora, Brule (Transect # 4)

The average number of white-tailed jackrabbits observed was 27.5 and numbers ranged from 23 to 32. The average density estimate was 1.56/km^2 with a range from 0.95/km^2 to 2.47/km^2 (Table 4*a*). Habitat availability was estimated to be 42% cultivated land and 58% grassland. Selection of agricultural habitat was evident during all surveys (Table 4*b*).

Hand, Hyde (Transect # 5)

The average number of white-tailed jackrabbits observed was 19.25 and numbers ranged from 17 to 27. The average density estimate was 1.40/km^2 with a range from 0.68/km^2 to 2.06/km^2 (Table 5*a*). Habitat availability was estimated to be 36% cultivated land and 64% grassland. No habitat preferences could be distinguished among surveys (Table 5*b*).

Edmunds, McPherson (Transect # 6)

The average number of white-tailed jackrabbits observed was 16.75 and numbers ranged from 8 to 24. The average density estimate was 1.07/km^2 with a range from 0.36/km^2 to 1.96/km^2 (Table 6*a*). Habitat availability was estimated to be 47% cultivated land and 53% grassland. During 2004, no preferences were apparent while in 2005 jackrabbits seemed to select grassland habitats (Table 6*b*).

McCook, Turner, Hutchinson (Transect # 7)

The average number of white-tailed jackrabbits observed was 18 and numbers ranged from 16 to 20. The average density estimate was 1.00/km^2 with a range from 0.70/km^2 to 1.35/km^2 (Table 7*a*). Habitat availability was estimated to be 82% cultivated land and 18% grassland. Habitat selection varied among surveys (Table 7*b*).

Bon Homme, Charles Mix, Douglas (Transect # 8)

The average number of white-tailed jackrabbits observed was 19.25 and numbers ranged from eight to 37. The average density estimate was 0.93/km^2 with a range from 0.29/km^2 to 1.99/km^2 (Table 8*a*). Habitat availability was estimated to be 69% cultivated land and 31% grassland. Habitat selection varied among surveys (Table 8*b*).

Brookings, Moody, Lake (Transect # 9)

The average number of white-tailed jackrabbits observed was 13.5 and numbers ranged from seven to 22. The average density estimate was 0.63/km^2 with a range from 0.49/km^2 to 1.01/km^2 (Table 9*a*). Habitat availability was estimated to be 71% cultivated land and 29% grassland. Habitat selection varied among surveys (Table 9*b*).

Deuel, Hamlin (Transect # 10)

The average number of white-tailed jackrabbits observed was 4.25 and numbers ranged from three to five. The average density estimate was 0.29/km^2 with a range from 0.20/km^2 to 0.41/km^2 (Table 10*a*). Habitat availability was estimated to be 62%

cultivated land and 38% grassland. No preferences could be distinguished among surveys, which is likely due to small sample size (Table 10*b*).

West River Transects

Nine of the 11 western South Dakota transects were 64.4 km (40 miles) in length, while the remaining two were slightly greater in length due to road availability. White-tailed jackrabbits were observed on all transects, while black-tailed jackrabbits were observed on only one transect in south central South Dakota. Ten of the 11 transects were surveyed three times while the remaining transect was surveyed twice due to inclement weather. Transects are listed in descending order from highest to lowest average density and include the name of the counties in which they lay. Maps of each transect can be found in Appendix II.

Harding, Butte (Transect # 11)

The average number of white-tailed jackrabbits observed was 346.7 and numbers ranged from 214 to 489. The average density estimate was $27.12/km^2$ with a range from $17.77/km^2$ to $51.20/km^2$ (Table 11*a*). Habitat availability was estimated to be 2% cultivated land and 98% grassland. Selection for agricultural habitat was observed in two surveys (Table 11*b*).

Perkins (Transect # 12)

The average number of white-tailed jackrabbits observed was 136.7 and numbers ranged from 91 to 199. The average density estimate was $7.91/km^2$ with a range from $7.63/km^2$ to $8.43/km^2$ (Table 12*a*). Habitat availability was estimated to be 47%

cultivated land and 53% grassland. Selection for agricultural habitat was observed during both fall surveys while no selection was observed in the spring survey (Table 12*b*).

Jones, Lyman (Transect # 13)

The average number of white-tailed jackrabbits observed was 38 and numbers ranged from 28 to 48. The average density estimate was 2.45/km^2 with a range from 2.14/km^2 to 3.03/km^2 (Table 13*a*). Habitat availability was estimated to be 50% cultivated land and 50% grassland. Selection for agricultural habitat was observed in the spring and fall surveys in 2005 and no selection was evident in the fall 2004 survey (Table 13*b*).

Fall River (Transect # 14)

The average number of white-tailed jackrabbits observed was 29.3 and numbers ranged from 26 to 32. The average density estimate was 2.34/km^2 with a range from 1.85/km^2 to 2.69/km^2 (Table 14*a*). Habitat availability was 26% cultivated land and 74% grassland. Habitat selection varied among surveys (Table 14*b*).

Meade, Pennington (Transect # 15)

The transect located in Meade and Pennington Counties was extended to 85.3 km (53 miles). The average number of white-tailed jackrabbits observed was 22 and numbers ranged from 9 to 30. The average density estimate was 1.15/km^2 with a range from 0.52/km^2 to 1.79/km^2 (Table 15*a*). Habitat availability was estimated to be 29% cultivated land and 71% grassland. Selection for agricultural habitat was observed during both surveys in 2005 while the fall 2004 survey showed no evidence of habitat selection (Table 15*b*).

Corson, Dewey (Transect # 16)

The transect located in Corson and Dewey Counties was extended to 70.8 km (44 miles). The average number of white-tailed jackrabbits observed was 12 and numbers ranged from eight to 21. The average density estimate was 0.98/km^2 with a range from 0.42/km^2 to 1.66/km^2 (Table 16*a*). Habitat availability was estimated to be 18% cultivated land and 82% grassland. Selection for agricultural habitat was observed during both fall surveys and no selection was observed during the spring 2005 survey (Table 16*b*).

Custer, Pennington (Transect # 17)

The average number of white-tailed jackrabbits observed was 6.7 and numbers ranged from 6 to 8. The average density estimate was 0.97/km^2 with a range from 0.55/km^2 to 1.94/km^2 (Table 17*a*). Habitat availability was estimated to be 13% cultivated land and 87% grassland. Selection for agricultural habitat was observed in the spring 2005 survey while no selection was observed during the fall surveys (Table 17*a*).

Stanley, Haakon (Transect # 18)

The average number of white-tailed jackrabbits observed was 14 and numbers ranged from seven to 22. The average density estimate was 0.93/km^2 with a range from 0.63/km^2 to 1.16/km^2 (Table 18*a*). Habitat availability was estimated to be 36% cultivated land and 64% grassland. Selection for agricultural habitat was observed during all three surveys (Table 18*b*).

Todd, Mellette (Transect # 19)

The average number of white-tailed jackrabbits observed was 10.3 and numbers ranged from six to 16. The average density estimate was 0.62/km^2 with a range from 0.46/km^2 to 0.82/km^2 (Table 19*a*). Habitat availability was estimated to be 24% cultivated land and 76% grassland. Selection for agricultural habitat was observed during both fall surveys and no selections were observed during the spring 2005 survey (Table 19*b*).

Tripp, Gregory (Transect # 20)

The transect located in Tripp and Gregory Counties in south central South Dakota was the only transect for which black-tailed jackrabbits were observed. During the three surveys we observed 26 jackrabbits, 9 of which were black-tails. The average jackrabbit density estimate was 0.54/km^2 with a range from 0.24/km^2 to 0.75/km^2 (Table 20*a*). Habitat availability was estimated to be 36% cultivated land and 64% grassland. No habitat selection was observed (Table 20*b*).

Shannon, Bennett (Transect # 21)

The transect located in Shannon and Bennett Counties was only surveyed twice due to inclement weather conditions during the fall 2005 survey period. The average number of white-tailed jackrabbits observed was 7.5 and numbers ranged from six to nine. The average density estimate was 0.43/km^2 with a range from 0.42/km^2 to 0.43/km^2 (Table 21). There were no habitat availability data for this transect.

DISCUSSION

Transect Design and Survey Procedures

Transects were designed to provide a baseline estimate of jackrabbit distribution and density. Since each transect length was 64.4 km, I was able to cover a substantial area to determine regional distribution and provide a density estimate. Individual transect surveys were completed in approximately four hours, which was a reasonable survey time to provide reliable results before succumbing to fatigue.

Previous researchers suggest that spring surveys be conducted in March and April before vegetation approaches peak height (Flinders and Hansen 1973, Smith and Nydegger 1985). Spring counts likely yield lower density estimates due to the breeding cycle for hares in northern latitudes such as South Dakota. Fall counts should be conducted in October and November to avoid standing crops, which may reduce visibility (Flinders and Hansen 1973, Plettner 1984, Smith and Nydegger 1985). Fall surveys should generate higher density estimates since breeding has ceased and juveniles have increased their activity making them more visible.

Due to agricultural practices and a late corn harvest, East River South Dakota was not surveyed until early to mid November. West River South Dakota transects were generally surveyed in October, with the westernmost transects surveyed first since agricultural practices are more conducive to an earlier sampling and grassland vegetation is naturally shorter than in eastern South Dakota. Spring surveys were not hindered by any environmental conditions.

Snow cover may influence visibility of white-tailed jackrabbits during certain portions of the year. In November, white-tailed jackrabbits were observed to have completely shed their brown pelage for their white winter coat, which reverted to brown in March. From November to March, white-tailed jackrabbits were highly visible during surveys if snow cover was absent. Conversely, surveys conducted during this time period when snow cover is present may have reduced visibility of white-tailed jackrabbits in winter pelages.

Several efforts were made to reduce violations of the assumptions for line-transect sampling set forth by Burnham et al. (1980). The driver and passenger focused observer efforts on their respective sides of the transect at a speed appropriate for accountability. The third person, the recorder, focused sighting efforts on the road which assured that all animals were spotted on the centerline. Since a rangefinder was used to measure perpendicular distances of hares from the transect, all measurements were thought to be accurate. I infrequently observed instances where the flushing of one hare provoked the flushing of a second. Hares were rarely, if ever, counted twice. Some animals may have been running prior to sighting but distances were measured from the point where they were first seen.

Species Distribution

White-tailed jackrabbits have been documented in all regions of South Dakota and their most recent predicted range includes the entire state (Higgins et al. 2000). Since white-tailed jackrabbits were observed on all transects, this study confirms a statewide distribution.

The distribution of the black-tailed jackrabbit has been thought to be expanding through much of the central midwest states as the white-tailed jackrabbit range seems to be shifting northward (Watkins and Nowak 1973). The most recent predicted northernmost range of the black-tailed jackrabbit extends well into south central and southwestern South Dakota (Higgins et al. 2000). The border of their probable range within South Dakota includes Pennington, Haakon, Stanley, Lyman, and Gregory Counties (see Higgins et al. 2000, p 66).

Efforts were made to distinguish species on all southern transects since black-tailed jackrabbits may occasionally be mistaken for white-tailed jackrabbits. In Colorado, Donoho (1972) reported that mistakes might be made during night observations for these sympatric species. I looked for the characteristic black stripe on the dorsal portion of the tail in identifying hares. The longer ears of the black-tailed jackrabbit may also be a diagnostic characteristic.

Black-tailed jackrabbits were observed during all three surveys conducted in Tripp and Gregory Counties, but only nine animals were recorded. I also examined road killed hares and searched other areas off established transects; however, black-tailed jackrabbit presence in portions of their predicted range in South Dakota was not confirmed. The black-tailed jackrabbit does not likely have a high density in South Dakota, but may be found in low numbers in the south central regions of South Dakota in Tripp and Gregory Counties. It is also possible that black-tailed jackrabbits reside in areas that cannot be easily accessed by roads such as the sandhills near the Nebraska state line.

Possible reasons for the black-tailed jackrabbit species northerly expansion includes a warming climate trend (Jones 1964) and an increase in tilled land (Brown 1947). Since black-tailed jackrabbits were not observed to have high densities in southern South Dakota, their expansion appears to be slow or non-existent at this time. Although white-tailed jackrabbits occupy areas throughout southern South Dakota and into northern Nebraska, further research should be conducted to evaluate interspecific competition with black-tailed jackrabbits. The habitat requirements of both species should be assessed to determine any changes that may be occurring in jackrabbit distribution (Dunn et al. 1982).

Density Estimation and Habitat Use

Density estimates are thought to be valid for each transect during each season, but limited inferences may be drawn on the regions each transect represents. Since seasonal surveys were conducted with a two-month time period, it was not feasible to perform replicate surveys of transects within seasons for this study. The calculated estimates provide baseline information on density of hares throughout regions in South Dakota.

There was a wide range of average density estimates in eastern South Dakota. White-tailed jackrabbits may be found in higher abundance in the James River Lowland than other areas of eastern South Dakota. The two highest density estimates came from transects within Beadle, Miner, and Sanborn Counties ($4.60/km^2$) and Brown and Spink Counties ($2.99/km^2$). Both transects lie within the central portion of eastern South Dakota, but the habitat availabilities varied between these two transects. The transect in

Beadle, Miner, and Sanborn Counties was estimated to be 68% grassland, the highest level of grassland availability in eastern South Dakota. White-tailed jackrabbits are thought to prefer short-grass prairie and are less adapted to cultivated land (Brown 1947, Higgins et. al 2000), therefore the observed results of the transect in Beadle, Miner, and Sanborn Counties was expected. However, the results of the transect in Brown and Spink Counties suggest that jackrabbits may exhibit substantial densities within cultivated habitats since grassland availability was only 2% on this transect.

White-tailed jackrabbits are less likely to be found in high abundance in extreme east central South Dakota. The two lowest density estimates were observed on transects lying within Deuel and Hamlin Counties (0.29/km^2) and Brookings, Moody, and Lake Counties (0.63/km^2).

Jackrabbit density also varied greatly in western South Dakota. The highest density was reported in Harding and Butte Counties (27.12/km^2) in extreme northwest South Dakota. This region had a considerably higher density estimate than any other region surveyed throughout the state. The northwestern portions of the state are ideal white-tailed jackrabbit habitat since it is partly characterized as Sagebrush Steppe, a Level IV ecoregion dominated by sagebrush with low human population, minimum cultivation, and a mean annual precipitation of only 13-14 inches (Bryce et al. 1998). Anecdotal reports also suggest a high level of predator control for livestock protection in the northwestern portions of the state.

The second highest density of western South Dakota also occurred in the northwest region in Perkins County (7.91/km^2). This county is immediately adjacent to

Harding and Butte Counties, but habitat types are more fragmented with only 53% grassland habitat availability. The transect in Harding and Butte Counties had a high availability of grassland habitat (98%), but chi-square analysis demonstrated that the animals were utilizing the 2% of available agricultural habitat. Similarly, jackrabbits in Perkins County demonstrated a selection for agricultural habitat despite availability of natural grassland habitat.

Jackrabbits were found to be in lower abundance in south central South Dakota. The lowest density estimates of jackrabbits in western South Dakota were observed in Shannon and Bennett Counties ($0.43/km^2$) and in Tripp and Gregory Counties ($0.54/km^2$). These regions are thought to be areas of black-tailed jackrabbit species expansion although there may be limiting factors in this region since high densities were not observed.

Overall, higher densities of jackrabbits were observed in areas with high grassland availability. There were no distinct patterns of habitat use demonstrated using chi-square analysis, although jackrabbits did demonstrate selection for agricultural habitat on several transects. Although white-tailed jackrabbits have been reported to select short-grass prairie, my surveys showed that jackrabbits selected for agricultural habitat during two or more surveys on eastern South Dakota transects # 1 and # 4 and western South Dakota transects # 11, # 12, # 13, # 15, # 16, # 18, and # 19. This selection may indicate that white-tailed jackrabbits utilize agricultural habitat for food resources and also provide evidence of their abilities to adapt to cultivated habitats.

RECOMMENDATIONS

The permanent routes created during this project may serve as a means for long term population monitoring of jackrabbits in South Dakota. Due to the small seasonal survey window, the development of several teams of surveyors may be the most useful means of collecting data. Transects should be surveyed three times within each two-month survey period (spring and fall) by individual teams. This method will provide better density estimates and may also be used to determine variation among surveys and seasons.

I recommend using program DISTANCE for analysis since it will provide unbiased density estimates that can be compared to the findings of this research. Surveying these transects may provide insight on reasons for cyclic fluctuations of jackrabbit populations. These routes may also be useful in monitoring species expansion or regression from their normal range. Special attention should be given to the south central regions of South Dakota to determine habitat use and competition between white-tailed jackrabbits and black-tailed jackrabbits.

In addition, predator-prey relationships may influence jackrabbit populations. During periods of no snow cover, white-tailed jackrabbits in their white pelage may be more susceptible to predation since they are more visible, which may be related to observed population fluctuations. Future research should include a comparison of jackrabbit and predator densities under different climatic conditions as well as the influence of predators on jackrabbit mortality.

Table 1*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Beadle, Miner, and Sanborn Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	51	2.73	14.0	2.06	3.60
Fall 2004	77	4.89	13.8	3.72	6.42
Spring 2005	70	3.20	24.0	2.00	5.14
Fall 2005	62	7.59	16.8	5.43	10.60
Mean	65	4.60			

* Represents animals per square km.

Table 1*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Beadle, Miner, and Sanborn Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 31% and grassland habitat represented 69% of this surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	51	41*	10	58.17
Fall 2004	77	26	51	0.28
Spring 2005	70	40*	30	22.37
Fall 2005	62	49*	13	66.87

*Indicates habitat selection.

Table 2*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Brown and Spink Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	35	4.10	27.9	2.35	7.14
Fall 2004	68	3.36	12.1	2.64	4.27
Spring 2005	59	2.40	13.0	1.85	3.11
Fall 2005	24	2.11	21.7	1.35	3.28
Mean	46.5	2.99			

* Represents animals per square km.

Table 2*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Brown and Spink Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 98% and grassland habitat represented 2% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	35	31	4*	15.87
Fall 2004	68	62	6*	16.15
Spring 2005	59	56	3	2.86
Fall 2005	24	22	2*	4.91

*Indicates habitat selection.

Table 3*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Day and Marshall Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	30	1.63	18.3	1.13	2.37
Fall 2004	28	1.66	18.9	1.13	2.44
Spring 2005	13	0.74	27.7	0.41	1.34
Fall 2005	27	5.18	32	2.71	9.89
Mean	24.5	2.30			

* Represents animals per square km.

Table 3*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Day and Marshall Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 68% and grassland habitat represented 32% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	30	13	17*	8.39
Fall 2004	28	19	9	0.00
Spring 2005	13	11	2	1.65
Fall 2005	27	20	7	0.46

*Indicates habitat selection.

Table 4*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Jerauld, Aurora, and Brule Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	23	0.95	20.9	0.62	1.46
Fall 2004	28	1.74	21.6	1.12	2.70
Spring 2005	32	2.47	21.7	1.59	3.82
Fall 2005	27	1.07	19.3	0.72	1.58
Mean	27.5	1.56			

* Represents animals per square km.

Table 4*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Jerauld, Aurora, and Brule Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 42% and grassland habitat represented 58% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	23	19*	4	15.57
Fall 2004	28	17*	11	4.03
Spring 2005	32	25*	7	17.14
Fall 2005	27	18*	9	6.74

*Indicates habitat selection.

Table 5*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Hand and Hyde Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	17	0.68	24.3	0.41	1.12
Fall 2004	22	1.96	25.6	1.16	3.32
Spring 2005	11	0.89	30.2	0.47	1.70
Fall 2005	27	2.06	20.9	1.35	3.15
Mean	19.25	1.40			

* Represents animals per square km.

Table 5*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Hand and Hyde Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 36% and grassland habitat represented 64% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	17	4	13	1.15
Fall 2004	22	6	16	0.73
Spring 2005	11	1	10	3.46
Fall 2005	27	11	16	0.26

*Indicates habitat selection.

Table 6*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Edmunds and McPherson Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	8	0.36	35.4	0.16	0.79
Fall 2004	24	1.96	20.4	1.29	2.98
Spring 2005	22	1.04	26.2	0.61	1.79
Fall 2005	13	0.91	27.7	0.5	1.63
Mean	16.75	1.07			

*Represents animals per square km.

Table 6*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Edmunds and McPherson Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 47% and grassland habitat represented 53% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	8	4	4	0.03
Fall 2004	24	11	13	0.01
Spring 2005	22	2	20*	12.69
Fall 2005	13	2	11*	5.22

*Indicates habitat selection.

Table 7*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in McCook, Turner, and Hutchinson Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	20	1.35	25.2	0.80	2.26
Fall 2004	18	1.08	23.6	0.67	1.77
Spring 2005	16	0.86	25.0	0.51	1.45
Fall 2005	18	0.70	23.6	0.43	1.14
Mean	18	1.00			

* Represents animals per square km.

Table 7*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in McCook, Turner, and Hutchinson Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 82% and grassland habitat represented 18% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	20	18	2	0.87
Fall 2004	18	8	10*	17.20
Spring 2005	16	15	1	1.50
Fall 2005	18	18*	0	3.95

*Indicates habitat selection.

Table 8*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Bon Homme, Charles Mix, and Douglas Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	8	0.29	35.4	0.13	0.64
Fall 2004	37	1.99	21.9	1.28	3.08
Spring 2005	14	0.56	26.7	0.32	0.99
Fall 2005	18	0.89	23.6	0.55	1.46
Mean	19.25	0.93			

* Represents animals per square km.

Table 8*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Bon Homme, Charles Mix, and Douglas Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 69% and grassland habitat represented 31% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	8	8	0	3.59
Fall 2004	37	14	23*	16.80
Spring 2005	14	13	1	3.73
Fall 2005	18	12	6	0.05

*Indicates habitat selection.

Table 9*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Brookings, Moody and Lake Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	22	1.01	21.3	0.65	1.56
Fall 2004	7	0.49	37.8	0.21	1.17
Spring 2005	8	0.54	35.4	0.24	1.18
Fall 2005	17	0.49	24.3	0.29	0.81
Mean	13.5	0.63			

* Represents animals per square km.

Table 9*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Brookings, Moody and Lake Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 71% and grassland habitat represented 29% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	22	20*	2	**4.24**
Fall 2004	7	5	2	**0.00**
Spring 2005	8	2	6*	**8.22**
Fall 2005	17	7	10*	**7.34**

*Indicates habitat selection.

Table 10*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Deuel and Hamlin Counties in eastern South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Spring 2004	5	0.41	44.7	0.14	1.21
Fall 2004	4	0.20	50	0.05	0.73
Spring 2005	3	0.27	58	0.05	1.51
Fall 2005	5	0.28	44.7	0.09	0.85
Mean	4.25	0.29			

* Represents animals per square km.

Table 10*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Deuel and Hamlin Counties in eastern South Dakota 2004 and 2005. Agricultural habitat represented 62% and grassland habitat represented 38% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Spring 2004	5	3	2	**0.01**
Fall 2004	4	2	2	**0.24**
Spring 2005	3	2	1	**0.03**
Fall 2005	5	4	1	**0.69**

*Indicates habitat selection.

Table 11*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Harding and Butte Counties in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	489	51.20	9.8	42.23	62.08
Spring 2005	214	12.38	12.1	9.76	15.70
Fall 2005	337	17.77	13.1	13.76	22.97
Mean	346.7	27.12			

*Represents animals per square km.

Table 11*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Harding and Butte Counties in western South Dakota 2004 and 2005. Agricultural habitat represented 2% and grassland habitat represented 98% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	490	27*	463	30.85
Spring 2005	214	18*	196	44.91
Fall 2005	337	0	337*	6.86

*Indicates habitat selection.

Table 12*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Perkins County in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	199	8.43	10.7	6.83	10.41
Spring 2005	91	7.63	11.9	6.04	9.66
Fall 2005	120	7.67	11.9	6.60	9.71
Mean	136.7	7.91			

*Represents animals per square km.

Table 12*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Perkins County in western South Dakota 2004 and 2005. Agricultural habitat represented 47% and grassland habitat represented 53% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	199	140*	59	43.73
Spring 2005	91	52	39	3.80
Fall 2005	120	85*	35	27.47

*Indicates habitat selection.

Table 13*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Jones and Lyman Counties in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	48	3.03	20.4	2.02	4.55
Spring 2005	38	2.14	16.2	1.54	2.96
Fall 2005	28	2.20	21.2	1.43	3.38
Mean	38	2.45			

* Represents animals per square km.

Table 13*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Jones and Lyman Counties in western South Dakota 2004 and 2005. Agricultural habitat represented 50% and grassland habitat represented 50% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	48	25	23	0.08
Spring 2005	38	29*	9	10.53
Fall 2005	28	23*	5	11.57

*Indicates habitat selection.

Table 14*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Fall River County in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	30	2.69	19.4	1.82	3.97
Spring 2005	26	1.85	25.1	1.11	3.08
Fall 2005	32	2.48	22.4	1.58	3.90
Mean	29.3	2.34			

* Represents animals per square km.

Table 14*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Fall River County in western South Dakota 2004 and 2005. Agricultural habitat represented 26% and grassland habitat represented 74% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	30	5	25	1.33
Spring 2005	26	2	24*	4.48
Fall 2005	32	15*	17	7.31

*Indicates habitat selection.

Table 15*a*. Spotlight surveys of jackrabbits on an 85.3-km (53-mile) transect in Meade and Pennington Counties in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	9	0.52	33.3	0.25	1.07
Spring 2005	27	1.14	19.3	0.77	1.68
Fall 2005	30	1.79	37.7	0.85	3.79
Mean	22	1.15			

* Represents animals per square km.

Table 15*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Meade and Pennington Counties in western South Dakota 2004 and 2005. Agricultural habitat represented 29% and grassland habitat represented 71% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	9	1	8	1.39
Spring 2005	27	15*	12	9.27
Fall 2005	30	14*	16	4.57

*Indicates habitat selection.

Table 16*a*. Spotlight surveys of jackrabbits on a 70.8-km (44-mile) transect in Corson and Dewey Counties in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	8	0.87	35.4	0.39	1.92
Spring 2005	7	0.42	37.8	0.18	0.99
Fall 2005	21	1.66	25.7	0.98	2.82
Mean	12	0.98			

* Represents animals per square km.

Table 16*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Corson and Dewey Counties in western South Dakota 2004 and 2005. Agricultural habitat represented 18% and grassland habitat represented 82% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	8	4*	4	5.55
Spring 2005	7	2	5	0.53
Fall 2005	21	13*	8	27.43

*Indicates habitat selection.

Table 17*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Custer and Pennington Counties in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	6	0.55	40.8	0.21	1.43
Spring 2005	6	0.42	40.8	0.16	1.09
Fall 2005	8	1.94	35.4	0.88	4.28
Mean	6.7	0.97			

* Represents animals per square km.

Table 17*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Custer and Pennington Counties in western South Dakota 2004 and 2005. Agricultural habitat represented 13% and grassland habitat represented 87% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	6	0	6	0.90
Spring 2005	6	4*	2	15.28
Fall 2005	8	1	7	0.00

*Indicates habitat selection.

Table 18*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Stanley and Haakon Counties in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	7	0.63	37.8	0.27	1.50
Spring 2005	13	1.00	27.7	0.56	1.81
Fall 2005	22	1.16	21.3	0.75	1.80
Mean	14	0.93			

* Represents animals per square km.

Table 18*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Stanley and Haakon Counties in western South Dakota 2004 and 2005. Agricultural habitat represented 36% and grassland habitat represented 64% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	7	6*	1	7.53
Spring 2005	13	9*	4	6.27
Fall 2005	22	17*	5	16.34

*Indicates habitat selection.

Table 19*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Todd and Mellette Counties in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	9	0.57	33.3	0.27	1.18
Spring 2005	6	0.46	40.8	0.18	1.20
Fall 2005	16	0.82	25.0	0.49	1.39
Mean	10.3	0.62			

* Represents animals per square km.

Table 19*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Todd and Mellette Counties in western South Dakota 2004 and 2005. Agricultural habitat represented 24% and grassland habitat represented 76% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	9	5*	4	4.91
Spring 2005	5	1	4	0.04
Fall 2005	16	14*	2	35.37

*Indicates habitat selection.

Table 20*a*. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Tripp and Gregory Counties in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate*	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	6	0.62	40.8	0.24	1.62
Spring 2005	15	0.75	25.8	0.44	1.29
Fall 2005	5	0.24	44.7	0.08	0.71
Mean	8.7	0.54			

* Represents animals per square km.

Table 20*b*. Habitat use of jackrabbits determined from a roadside spotlight transect in Tripp and Gregory Counties in western South Dakota 2004 and 2005. Agricultural habitat represented 36% and grassland habitat represented 64% of the surveyed transect. Chi-square critical value = 3.84.

Survey	Hares Observed	Hares in Agr. Land	Hares in Grassland	Chi Square Value
Fall 2004	6	2	4	0.02
Spring 2005	15	3	12	1.67
Fall 2005	5	1	4	0.56

*Indicates habitat selection.

Table 21. Spotlight surveys of jackrabbits on a 64.4-km (40-mile) transect in Shannon and Bennett Counties in western South Dakota, 2004 and 2005.

Survey	Hares Observed	Density Estimate	Percent Coeff. Of Variation	Lower Conf. Limit	Upper Conf. Limit
Fall 2004	6	0.42	40.8	0.16	1.09
Spring 2005	9	0.43	33.3	0.21	0.90
Fall 2005†					
Mean	7.5	0.43			

* Represents animals per square km.

† Survey not completed.

CHAPTER 3. REPRODUCTIVE CHARACTERISTICS, BODY CONDITION, DISEASE AND PARASITES OF WHITE-TAILED JACKRABBITS IN SOUTH DAKOTA

INTRODUCTION

Reproductive information on white-tailed jackrabbits exists in portions of their range (Kline 1963, James and Seabloom 1969, Rogowitz 1992); however, little information exists about jackrabbit biology in South Dakota. Reproductive output may influence fluctuations in jackrabbit populations, especially during peak carrying capacity. In some jackrabbit populations, reproduction may be controlled by density-dependent variables (French et al. 1965). As with most leporids, white-tailed jackrabbits are capable of producing multiple litters per season but reproductive output may vary geographically (Conaway et al. 1974, Flux 1971, Keith 1981, Dunn et al. 1982, Rogowitz 1992). Jackrabbits demonstrate induced ovulation which may explain their tendency for postpartum breeding and may lead to synchronous breeding (Lechleitner 1959a, Kline 1963, James and Seabloom 1969, Dunn et al. 1982, Rogowitz 1992).

The breeding season of white-tailed jackrabbits typically begins in late February and extends through mid July (Dunn et al. 1982). In Iowa and North Dakota, the breeding season lasted 148 days (Kline 1963, James and Seabloom 1969) while a 146 day breeding season was noted in southwestern Wyoming (Rogowitz 1992). White-tailed jackrabbits produce three to four litters per year in both North Dakota (James and Seabloom 1969) and Iowa (Kline 1963). The gestation period for white-tailed jackrabbits is 42-43 days (Kline 1963, Higgins et al. 2000).

Seasonal energy expenditures may provide insight on several aspects of jackrabbit reproductive behavior. In Wyoming, Rogowitz (1992) attributed inadequate nutrition and gonadal tissue catabolism in white-tailed jackrabbits to decreased reproductive output as well as decreased fat retention. Riney (1955) proposed using a kidney fat index as a measure of physical condition for animals. Kidney weight may serve as an indicator of metabolic activity assuming the size of the kidney is related to the amount of active body tissue and metabolic rate (Flux 1971). Perirenal fat, one of the main fat deposits, is easily accessible and measurable while producing a wide scale of values under regular environmental circumstances (Riney 1955, Flux 1971).

Disease may also contribute to factors that govern *Lepus* spp. population fluctuations. Tularemia, caused by infection with the bacteria *Pasturella tularense,* is a fatal disease that is diagnosed in jackrabbits by small, round, white lesions on the liver and spleen (Lechleitner 1958). Tularemia can sporadically occur in lagomorph populations and may lead to epidemic proportions when vectors such as ticks and flies are abundant (Lechleitner 1959b). In South Dakota, Kietzmann and Hugghins (1984) examined white-tailed jackrabbits for parasites but the collected animals were not tested for tularemia.

OBJECTIVES

The objectives of this research were to: (1) determine sex and age ratios, (2) determine reproductive potential, (3) determine seasonal body condition using a kidney fat index, and (4) assess the presence of tularemia or any other abnormalities. This information will provide insight on the current biological status of white-tailed jackrabbits throughout South Dakota.

METHODS

Collection

White-tailed jackrabbits were collected in 44 counties throughout South Dakota from June 2004 to September 2005. I attempted to collect 15-20 jackrabbits each month using a .22 caliber rifle in isolated areas of each county between 1600 and 2200 hours. Collected jackrabbits were fitted with an individual ear tag, placed in a plastic bag, and either necropsied immediately or frozen for later examination. Additional jackrabbits were received from South Dakota Department of Game Fish and Parks personnel. Ellsworth Airforce Base personnel also provided jackrabbits that were removed from runways.

Age Determination and Classification

Age of collected jackrabbits was estimated using the epiphyseal closure method (Hale 1949, Lechleitner 1959a, James and Seabloom 1969). X-ray analysis (0.15 second exposure time) was used to determine epiphyseal closure in the left humerus of collected jackrabbits. If the left humerus was damaged during collection, the right humerus was used. Jackrabbits were classified into three age classes based on the amount of closure observed on the proximal epiphysis of the humerus: Age Class 1, (two to nine months) where the epiphyseal area has a definite groove; Age Class 2, (10 to 12 months) in which the epiphysis is essentially closed; Age Class 3, (over one year old) where there is no evidence of an epiphyseal line (Lechleitner 1959a).

In addition to aging animals using the epiphyseal closure method, adult males were differentiated by the appearance of the scrotum. Adult male white-tailed jackrabbits may possess a scrotal sac that is darker and covered with less hair than those of younger males (James and Seabloom 1969). Lechletiner (1959a) reported this condition in black-tailed jackrabbits and suggested this as an attribute of older animals.

Reproductive Activity

Post-mortem examinations involved assessing the reproductive condition of both sexes using methods described by James and Seabloom (1969) and Gross et al. (1974). Sexual activity of males was determined by measuring the mass of paired testes after the epididymides were removed. I also recorded whether or not testes were scrotal for adult males.

Reproductive potential was determined from several female characteristics. Sexual activity of females was determined by measuring the mass of paired ovaries. Fetuses were removed and counted from gravid female white-tailed jackrabbits. Litter size was defined as the total number of viable fetuses per female (Rogowitz 1992). Following methods similar to James and Seabloom (1969), fetal age was approximated by comparing developmental and morphological characteristics as well as crown-rump lengths to those of the snowshoe hare (Bookhout 1964). I approximated the date of conception by back-dating the estimated fetal age from the date of collection. Parturition dates were determined by adding the gestation period of 43 days to conception dates (James and Seabloom 1969, Rogowitz 1992). The breeding season was defined as the length of time between the first conception date and the last conception date (James and

Seabloom 1969). The annual potential number of litters was calculated by dividing the length of the breeding season by the 43-day gestation period.

Prenatal Mortality

Ovaries removed from gravid female jackrabbits were preserved in a 10% formalin solution and sectioned to macroscopically count corpora lutea. Each corpus luteum represented the number of ova shed per ovary. Corpora lutea were only indicative of ova shed for that littering period because those of previous litters are generally inconspicuous (James and Seabloom 1969). Prenatal mortality was estimated from the amount of litter loss experienced from pre-implantation and post-implantation loss (Lechleitner 1959a). Pre-implantation loss was defined as failure of ova to implant within the uterine wall and was estimated by subtracting the number of ova produced (corpora lutea) from the number of implantation sites. Post-implantation loss was measured by resorption of implanted embryos and was calculated by subtracting the number of implantation sites from the number of viable fetuses. Resorbing fetuses were identified as swellings that appeared distinctly smaller than viable fetuses (Bookhout 1964). Both causes of prenatal mortality were then incorporated as (prenatal loss per litter) / (# ova shed) X 100 to calculate a percent prenatal mortality for each littering period (Lechleitner 1959a).

Kidney Fat Index and Kidney Weight

Body condition was assessed by measuring the amount of kidney fat within each collected jackrabbit. Kidneys and all perirenal fat associated with the kidneys were removed and weighed from jackrabbits collected from August 2004 to September 2005.

The kidney fat index was calculated as (total kidney fat weight) / (kidney weight) x 100, and is expressed as a percent (Riney 1955). Kidney weight was measured to determine months of high metabolic activity as indicated by an increase in mass. If kidneys were damaged in the collection process, those jackrabbits were omitted from examination. Two sample t-tests were used to detect any differences in kidney weight between the sexes ($\alpha = 0.05$).

Abnormalities

All collected jackrabbits were examined for presence of tularemia and/or any other abnormalities. Preliminary diagnosis was accomplished by macroscopic examination of the liver and spleen for small, round, white lesions (Lechleitner 1958). Animals that possessed abnormalities within these or any other organs were sent to the Veterinary Science Department at South Dakota State University for further diagnosis.

RESULTS

Sex Ratios

A total of 314 white-tailed jackrabbits were collected throughout the study. The number of jackrabbits collected monthly ranged from six to 44 ($\bar{x} = 19$). There were 161 males and 153 females, which was not different than an expected 1:1 sex ratio ($\chi2 = 0.204$) (Figure 1).

Age Ratios

Age was estimated for 264 white-tailed jackrabbits (Figure 2). The remaining animals were not included due to damage of the humerus in the collection process or cartilage decomposition during freezing. There were 171 jackrabbits classified as adults

(Age Class 3). This age class was present in all months of collection. Age class 2 (n=18) jackrabbits were only collected between October 2004 and March 2005. The remaining 75 collected jackrabbits were classified as juveniles (Age Class 1). These animals were collected from June 2004 through December 2004, and May 2005 through the remainder of the collection period in September 2005.

Reproductive Activity

An annual pattern of reproductive activity was demonstrated by weight fluctuations of reproductive organs in both sexes of white-tailed jackrabbits. In males, there were dramatic reductions in average paired testes weights from June (15.55g; SE 3.89) to July (3.42g; SE 0.71) in 2004. In 2005, average testicular weight also regressed from June (12.76g; SE 2.97) to July (2.41g; SE 0.25). These reductions suggest a cessation in reproductive activity during July in both 2004 and 2005 breeding seasons.

There was a marked increase in testicular turgidity and weight from December 2004 (2.50g; SE 0.50) to January 2005 (9.52g; SE 1.89) and again in February (18.94g; SE 1.51). This progression indicates male reproductive activity began in January. Peak testicular weight was observed in March 2005 (24.92g; SE 1.11) (Figure 3).

Ovarian mass fluctuations in female white-tailed jackrabbits (Figure 4) were similar to male testicular fluctuations, although female sexual activity appeared to be one month behind males especially during the 2004 breeding season. During the end of the 2004 breeding season, there was a decrease in ovarian weight from July (1.47g; SE 0.24) to August (0.81g; SE 0.11) and again in September (0.45g; SE 0.13). Ovarian weight increased sharply from January 2005 (0.43g; SE 0.04) to February (0.82g; SE 0.08) and peaked in March (2.16g; SE 0.21). Female reproductive activity ceased in August 2004 and began in February 2005, approximately one month later than males.

Breeding Synchrony and Reproductive Potential

Breeding synchrony was evident in both breeding seasons as indicated by an overlap of estimated conception and parturition dates (Table 1). Further support for breeding synchrony was evident when identical stages of fetal development were observed in gravid females during any given week of collection. All gravid female jackrabbits collected during the same week were in a similar stage of gestation.

2004 Breeding Season

In June, eight of the 10 adult female jackrabbits were pregnant. From the estimated conception dates, females collected in June likely represented the third littering period. Conception dates for each female were estimated from May 22 to May 27 and subsequent parturition dates were estimated from July 3 to July 8. Litter size ranged from four to eight and averaged 5.5 (SE 0.50) per female.

In July, two of seven adult females were pregnant and one of ten adult females was pregnant in August. Estimated conception dates for these females were July 4, July 6, and July 17. Since the estimated conception dates overlap with parturition dates of the third littering period, these three females likely represented the fourth litter in 2004. Litter size ranged from four to seven and averaged 5.0 (SE 1.0) per female during the fourth littering period (Table 1). Due to timing of collection, the length of the 2004 breeding season was not determined.

2005 Breeding Season

The breeding season began in February based on the first pregnant female's estimated conception date (Feb 24). Further support for an increase in reproductive activity was demonstrated by the progression of ovarian and testicular weight during this time period. In March, all 13 collected adult female jackrabbits were pregnant with conception dates estimated from February 24 to March 6. Parturition dates were estimated from April 7 to April 17. Litter size ranged from one to seven and averaged 4.2 (SE 0.46) per female.

The second littering period was determined by the overlap of conception dates demonstrated by three gravid females collected in April and one collected in May. Estimated conception dates for these four females were from March 29 to April 16. There were approximately two weeks of overlap between the first littering period parturition dates and the second littering period conception dates. Parturition dates for the second littering period were from May 10 to May 28. Litter size ranged from five to eight and averaged 6.0 (SE 0.71) during the second littering period.

There were six gravid females collected in June and one in July that were estimated to conceive from May 27 to June 9. These conception dates were approximately two weeks after parturition of females in the second littering period, therefore these females likely represented the third littering period. Parturition dates for these females were estimated from July 8 to July 21. Litter size for the third littering period ranged from three to six and averaged 4.7 (SE 0.42) per female.

In August, two of the 11 adult females collected were gravid with estimated conception dates of June 30 and July 15. These females likely represented the potential fourth littering period since conception dates overlap with parturition dates of the third littering period. Parturition dates for the fourth littering period were estimated to be August 12 and 26. Both females were carrying three viable fetuses.

The length of the breeding season, calculated by summing the days between the first conception date (Feb 24) and the last conception date (Jul 15) was estimated to be 142 days, allowing for 3.3 litters.

Prenatal Mortality

2004 Breeding Season

Prenatal mortality occurred in one gravid female white-tailed jackrabbit collected in June that demonstrated resorption of one fetus making the total prenatal mortality 2%. This female was estimated to conceive during the third littering period. There were no instances of prenatal mortality during the fourth littering period. Prenatal mortality from pre-implantation loss was not observed in any parous female jackrabbits that were collected.

2005 Breeding Season

Prenatal mortality was greatest (32%) in the first littering period. There were 79 ova shed from the 13 collected females with only 54 implantation sites. Two females also showed evidence of resorption at one implantation site during the first littering period. In the second littering period, 25 ova were shed with 24 viable fetuses since one female exhibited resorption of one fetus (4% prenatal mortality). During the third littering period there were 35 ova shed with only 33 implantation sites. Pre-implantation loss of one ova and one instance of resorption resulted in 6% prenatal mortality in the third littering period. Prenatal mortality was 14% in the fourth littering period. Pre-implantation loss was the only source of prenatal mortality with seven ova shed and only six implantation sites.

Since there were 26 gravid females collected in 2005 that shed 146 ova over four littering periods, the potential annual production was 22.5 per female (Table 2). Reproduction of white-tailed jackrabbits in South Dakota is summarized in Table 3.

Kidney Fat Index and Kidney Weight

I examined 243 (126 male, 117 female) white-tailed jackrabbits for calculation of a kidney fat index and to determine monthly fluctuations in kidney weights. Perirenal fat reserves fluctuated monthly in both sexes (Figure 5). Male kidney fat gradually rose from August (38.4%) to December (84.1%). There was a dramatic increase in January (177.5%) and a peak occurred in February (269.4%). Kidney fat began to regress in March (107.3%) and April (68.3%) and reached 0% in June.

The kidney fat index for females also gradually increased from August (13.2%) to November (74.8%) and sharply rose in December (132%). Female kidney fat peaked in January (208.2%), and then a downward trend began in February (169.1%) and April (108.4%) and reached 0% in June.

Monthly fluctuations were also evident in average kidney weight for both sexes of white-tailed jackrabbits. For females, average kidney weight was highest in November (10.48g; SE 0.05) and April (10.31g; SE 0.51) and lowest in July (7.28g; SE 0.62)

(Figure 6). In male jackrabbits, average kidney weight was highest in December (9.43g; SE 0.29) and May (9.62g; SE 0.26), and lowest in July (6.17g; SE 0.31) (Figure 7). The average female kidney weight (9.32g; SE 0.17) was not significantly different from average male kidney weight (7.92g; SE 0.15) (p=0.19).

Abnormalities

No confirmed instances of tularemia were found during post mortem examination of 314 white-tailed jackrabbits. However, four jackrabbit livers contained the nematode *Capillaria hepatica*. Infected livers contained white cysts filled with double operculated eggs of *C. hepatica* which produced multi-focal hepatitis. Three infected jackrabbits (two male, one female) were collected in Kingsbury County during January 2005 and one infected male jackrabbit was collected in Perkins County in April 2005.

An additional parasite was identified as the tapeworm *Multiceps serialis* (Regg Neiger, SDSU Veterinarian, pers. commun.) in a collected female white-tailed jackrabbit from Kingsbury County. A large parasitic cyst with clear fluid and numerous white, 2 mm long floating objects was detected in the right lumbar muscle. The volume of the cyst was 40 ml and contained numerous intramural larval cestode buds, each bearing an armed scolex.

Another abnormality was the presence of large multi-focal lesions in the liver of a male jackrabbit collected in Brookings County in April 2005. The lesions were diagnosed as an abscess formation caused by the bacteria *Listeria monocytogen* (Regg Neiger, SDSU Veterinarian, pers. commun.).

DISCUSSION

Sex Ratios

There is a paucity of information on sex ratios of white-tailed jackrabbits, but this research indicates that sex ratios are similar to those of black-tailed jackrabbits which have been reported to be 1:1 throughout much of their range (Lechleitner 1959a, Tiemeier 1965, Gross et al. 1974, Dunn et al. 1982, Plettner 1984). Some researchers believe that certain methods of collection may result in skewed sex ratios. Lechleitner (1959a) suggested that collections made with a rifle may be biased toward males in the peak of the breeding season because males are more active than females during the day. Gross et al. (1974) found that night shooting during the breeding season may be biased toward females because they have higher energy requirements for lactation and pregnancy, resulting in increased movements and feeding, making them more susceptible to collection. No distinct collection biases toward either sex were evident during this study.

Age Ratios

Jackrabbits in Age Class 1 are generally not collected until they are about three months old due to their secretive behavior (Lechleitner 1959a). Age Class 1 jackrabbits appear during April in Nebraska (Plettner 1984) and during May in California (Lechleitner 1959a). Approximately 28% of the jackrabbits I collected were Age Class 1 and were found from May to December. Lechleitner (1959a) found Age Class 1 black-tailed jackrabbits through December which is probably when most Age Class 1 jackrabbits become Age Class 2.

Age Class 2 represented 7% of the 264 white-tailed jackrabbits examined. Although this age class was collected from October 2004 to March 2005, their numbers peaked in November and December. Chronologically, all juveniles should have progressed into Age Class 2 during that time and should have been approaching Age Class 3. In California, Lechleitner (1959a) reported that Age Class 2 jackrabbits reached their peak in the collection during March.

Age Class 3 represented 65% of the total number of white-tailed jackrabbits collected. Most jackrabbits collected in March and all collections in April were classified as Age Class 3. Lechleitner (1959a) and Plettner (1984) also found a high percentage of Age Class 3 animals during April. This suggests that the majority of Age Class 2 animals have progressed to Age Class 3 by March and April.

There have been many suggestions for the cause of fluctuations in lagomorph populations; however, little data exists to evaluate these explanations (Rogowitz and Wolfe 1991). Prolific breeding capabilities in lagomorphs may aid in sudden population increases. White-tailed jackrabbit populations are composed mostly of adults in winter while juveniles dominate in other seasons (James and Seabloom 1969, Rogowitz and Wolfe 1991). Since most juveniles became Age Class 3 by March or April in 2005, the entire population would potentially be capable of breeding by the second littering period. In Wyoming, Rogowitz and Wolfe (1991) reported a rapid rate of population replacement of adults by juveniles which may have prevented a population decline during times with low survival.

Reproductive Characteristics

Male white-tailed jackrabbits were scrotal from January until July 2005, which is similar to white-tailed jackrabbits in North Dakota (James and Seabloom 1969). This condition may be used as an attribute to detect sexual activity, but should be considered in conjunction with testicular weights. When hares become excited or are in shock, testes may retract into the patent inguinal canal (Lechleitner 1959a, James and Seabloom 1969) which may lead to false conclusions about individual reproductive activity.

From examining scrotal animals and measuring testicular weights, adult male white-tailed jackrabbits were reproductively active from January to July during the 2005 breeding season. Testicular weights of adult male jackrabbits increased 380% from December to January, indicating a dramatic increase in sexual activity and an increase in potency and fertility. Average testicular weights again doubled (199%) from January to February. Testes weights peaked in March 2005 and remained constant through June. In July, average testicular weights reduced to less than 20% of the weight observed in June indicating male reproductive activity ceased in July. When male hares cease breeding, testicular weights diminish causing a loss of libido and potency (Meslow and Keith 1968, James and Seabloom 1969).

In female white-tailed jackrabbits, the average ovarian weight increased 191% from January to February. There was another sharp increase of 263% from February to the peak month of March. This progression suggests that female reproductive activity began sometime between late February and early March. This assumption is supported by the estimated conception dates in the last week of February and the first week of

March for all females collected in March. In North Dakota, white-tailed jackrabbits peaked in ovarian weight between February and March which was attributed to maturation of follicles and corpora lutea formation (James and Seabloom 1969).

There appears to be a time difference of one month in the onset and cessation of breeding between sexes of white-tailed jackrabbits. Ovaries of female jackrabbits increase in mass one month after testes of males and remain at their maximum until one month after male testes begin to regress in mass. A lag period in cessation of breeding was less evident in 2005 which is likely a result of low sample size of Age Class 3 jackrabbits (n=4) in August. White-tailed jackrabbits also demonstrated a lag period in North Dakota (James and Seabloom 1969).

Breeding Synchrony

Breeding synchrony was most evident in the first littering period during the 2005 breeding season. The characteristic post-partum heat demonstrated by *Lepus* spp. may increase the instances of breeding synchrony but synchrony must be present within the first littering period (James and Seabloom 1969). The fact that essentially all males are reproductively active when females first become receptive ultimately results in synchrony of the first littering period. Cues that result in a synchronous estrous cycle of females are likely responsible for synchrony of subsequent litters. Rogowitz (1992) implied that cues other than ambient temperature stimulate reproductive activity and suggested that snow cover and food accessibility may play a role in the onset of reproduction in white-tailed jackrabbits.

White-tailed jackrabbits may annually produce three to four litters but only a small percentage of females actually produce four litters per season. James and Seabloom (1969) found that only 29% of female white-tailed jackrabbits in North Dakota produced a fourth litter. In both 2004 and 2005, 18% of the adult females that were collected experienced a fourth littering period. Since most males become reproductively inactive one month before females, it would suggest that only a small percentage of males are sexually available to a receptive female during the potential fourth littering period. However, the number of females that experienced a fourth estrous cycle was not determined, therefore future research should include counting corpora lutea for non-pregnant parous females throughout the breeding season to determine the percentage of females that are capable of producing a fourth litter.

Prenatal Mortality

Prenatal mortality will affect overall reproductive output of female white-tailed jackrabbits. I was able to estimate prenatal mortality for the last two littering periods during the 2004 breeding season. Mortality resulting from post-implantation loss was documented in only one gravid female white-tailed jackrabbit. There were 56 ova shed among 11 gravid white-tailed jackrabbits, indicating post-implantation loss affected 1.8% of all ova shed and 9.1% of females collected in 2004. Pre-implantation loss was not observed in any jackrabbits in 2004.

In 2005, post-implantation loss affected only four gravid females. There were 146 ova shed from 26 gravid female jackrabbits, resulting in post-implantation loss affecting 2.7% of all ova shed and 15.4% of all gravid females collected. Pre-implantation loss was observed in gravid female white-tailed jackrabbits during the first and third littering periods in 2005. Bronson and Tiemeier (1958) reported that resorption was a result of stress such as weather conditions, which if great enough, may result in entire litter loss.

Instances of prenatal mortality varied among littering periods throughout the 2005 breeding season. Prenatal mortality was greatest in the first littering period in 2005, (32%) and sharply decreased during the second (4%) and third (6%) littering periods, and rose during the fourth littering period (14%). Due to small sample size in the fourth littering period (n=2), this figure may be inaccurate. Inadequate nutrition has been demonstrated to increase instances of prenatal mortality of first litters and reduce fertility in jackrabbits (Rogowitz 1992).

Reproductive output of female white-tailed jackrabbits may vary between littering periods. In North Dakota, the average number of ova shed by female white-tailed jackrabbits steadily decreased throughout the breeding season (James and Seabloom 1969). The mean number of ova shed by female white-tailed jackrabbits in South Dakota was greatest during the first two littering periods, 6.1 and 6.3 respectively, followed by a downward trend in the third (5.0) and fourth (3.5) littering periods. In Wyoming, Rogowitz (1992) found that reproductive output among white-tailed jackrabbits varied with environmental conditions and energy expenditure for fetal production was greater when suitable forage became available.

Kidney Fat Index and Kidney Weight

Wild animals are unlikely to retain unnecessary fat during any given time of the year (Flux 1971). I found that both sexes of white-tailed jackrabbits retained more perirenal fat during winter months. The kidney fat index for both sexes steadily increased from August 2004 to November and December, and then rose sharply in January 2005, likely due to cold weather and availability of food resources. The male kidney fat index peaked in February while females peaked in January. After peak months, regression in perirenal fat was observed for both sexes, perhaps due to increased activity during the onset of breeding. As the breeding season progressed, the kidney fat index for both sexes gradually decreased and reached 0% during June, at which point it began to increase again.

Although sexual dimorphism occurs in white-tailed jackrabbits, females did not exhibit significantly greater size in average kidney weight. Physiological activity patterns based on fluctuations of average kidney weights were evident in both sexes. The lowest kidney weights for both sexes were during periods of extreme cold weather in January and hot weather in July. The inclement weather conditions occurring during these time periods may have inhibited normal activity resulting in lower average kidney weights.

Abnormalities

Tularemia was not prevalent in South Dakota white-tailed jackrabbit populations throughout this study since there were no instances in any specimen examined. It is possible that prevalence of *P. tularense* and abundance of known vectors was low within sampled areas during this time period. Lechleitner (1958) found eight black-tailed jackrabbits infected with tularemia in California and recommended that the public be notified in similar instances. A hare that exhibits distressed behavior or appears sick must never be handled and all meat from harvested jackrabbits should be cooked thoroughly (Lechleitner 1958).

The presence of *C. hepatica* in four jackrabbits was unusual due to the nematode's life cycle. Perpetuation of this parasite is typically achieved from the ingestion of infective ova from an infected liver during predation, cannibalism, or scavenging (Farhang-Azad 1977).

Figure 1. Monthly sex ratios of 314 white-tailed jackrabbits collected in South Dakota, 2004-2005.

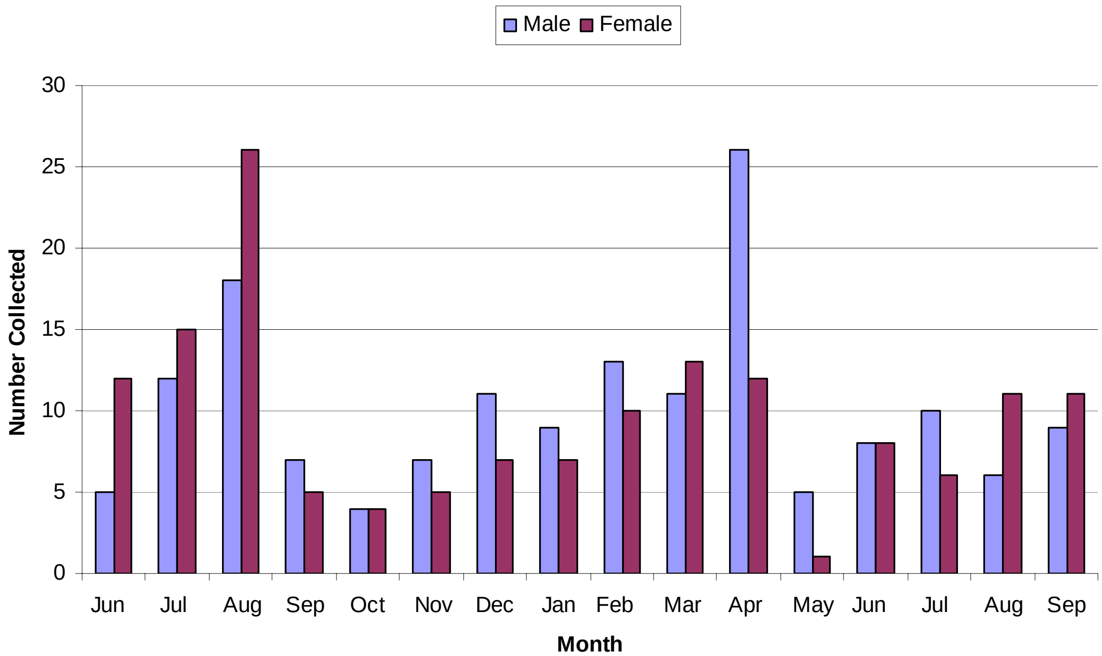

Figure 2. Age distribution of 264 white-tailed jackrabbits collected in South Dakota, 2004-2005.

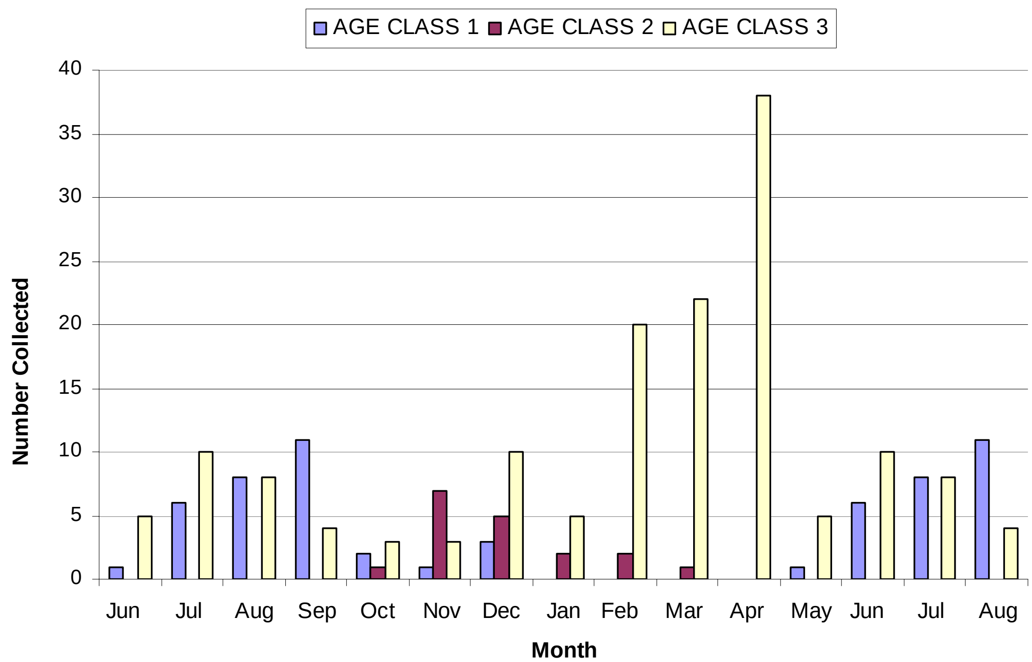

Figure 3. Mean testicular weights of white-tailed jackrabbits in South Dakota 2004-2005. Vertical lines represent the highest and lowest observed value.

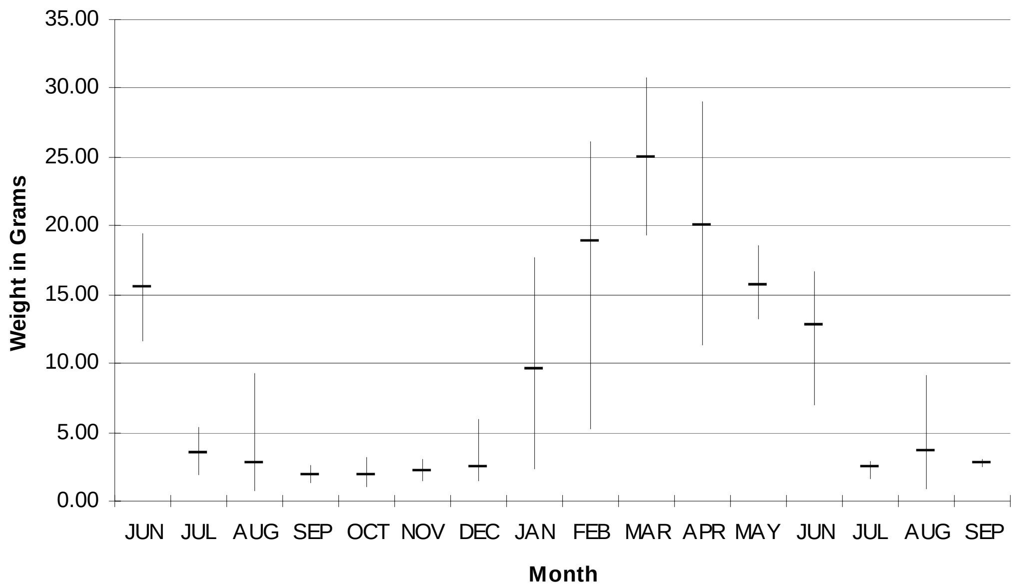

Figure 4. Mean ovarian weights of white-tailed jackrabbits in South Dakota 2004-2005. Vertical lines represent the highest and lowest observed value.

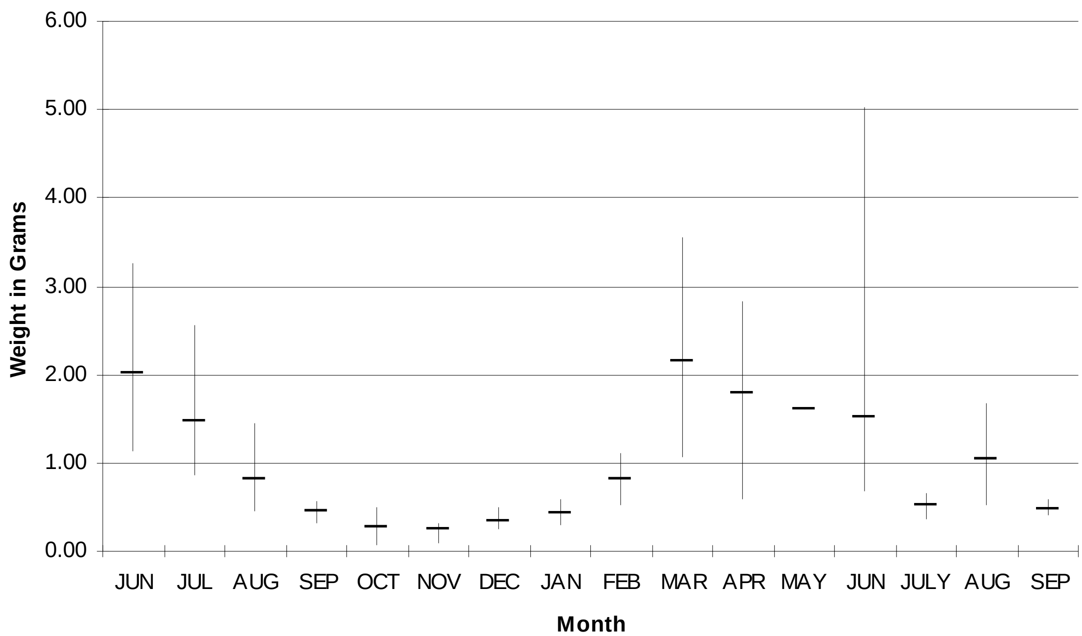

Figure 5. Kidney fat index for collected white-tailed jackrabbits in South Dakota 2004-2005.

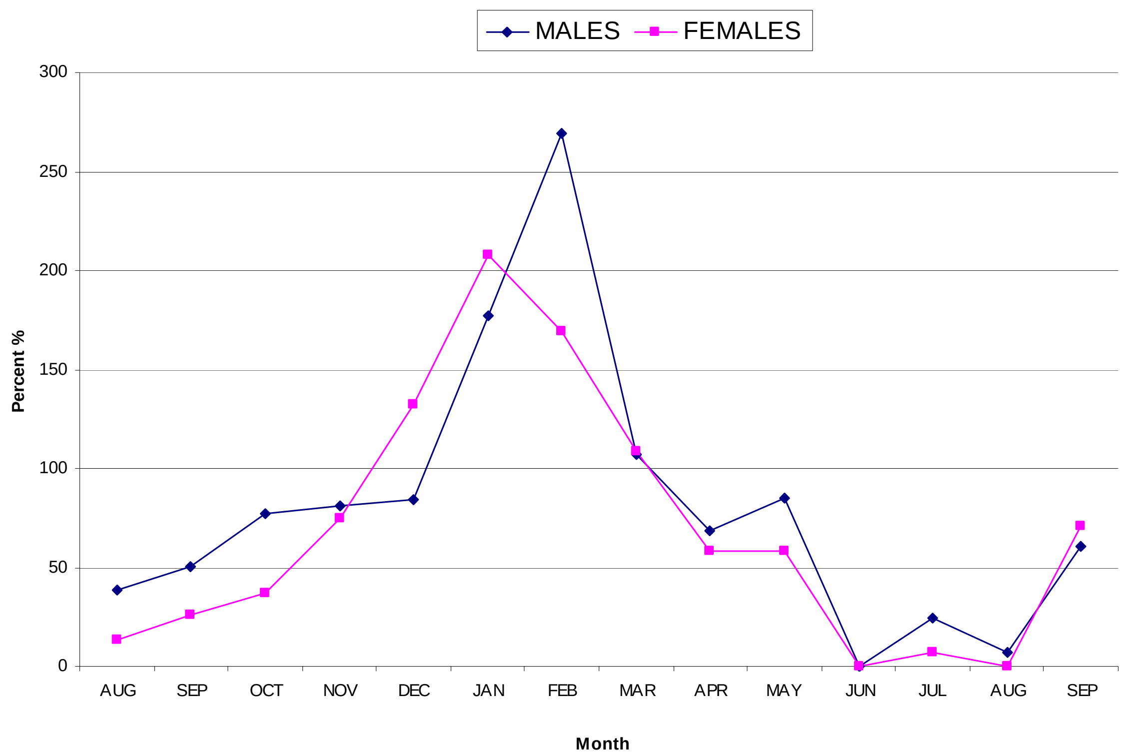

Figure 6. Mean kidney weights of female white-tailed jackrabbits in South Dakota 2004-2005. Vertical lines represent the highest and lowest observed values.

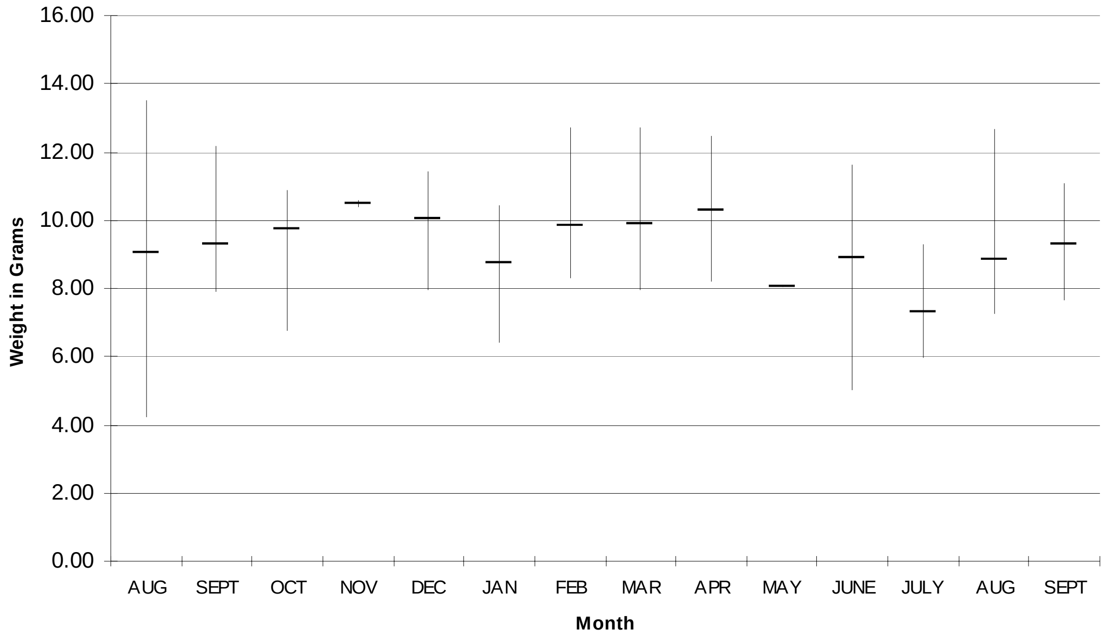

Figure 7. Mean kidney weights of male white-tailed jackrabbits in South Dakota 2004-2005. Vertical lines represent the highest and lowest observed values.

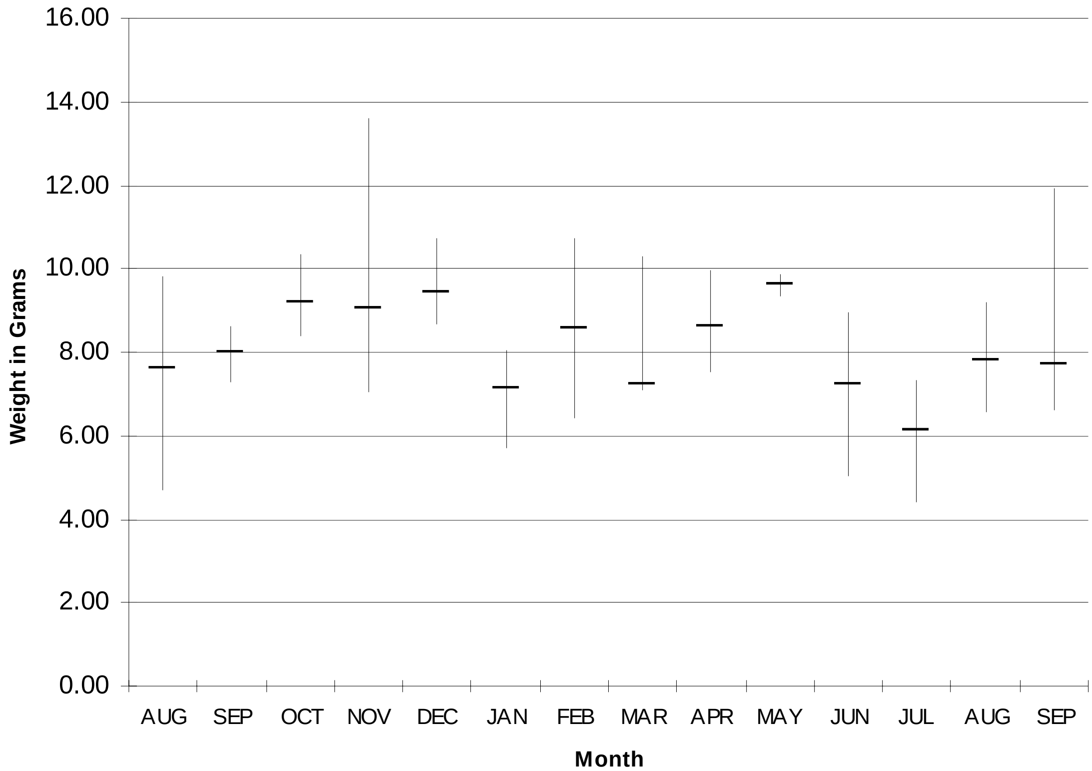

Table 1. Estimated conception and parturition dates of white-tailed jackrabbits in South Dakota, 2004 and 2005.

Year	Littering Period	Gravid Females	Conception Dates	Parturition Dates
2004	3	8	22 May - 25 May	3 Jul - 8 Jul
	4	3	4 Jul - 17 Jul	16 Aug - 29 Aug
2005	1	13	24 Feb - 6 Mar	7 Apr - 17 Apr
	2	4	29 Mar - 16 Apr	10 May - 28 May
	3	7	27 May - 9 Jun	8 Jul - 21 Jul
	4	2	30 Jun - 15 Jul	12 Aug - 26 Aug

Table 2. Reproductive potential of female white-tailed jackrabbits collected in South Dakota, 2004 and 2005.

Year	Gravid Females	Ova Shed	Mean Potential Litter Size	Number of Potential Litters	Potential Annual Production per Female
2004*	11	56	5.1	2	10.2
2005	26	146	5.6	4	22.5

*Includes only 2 littering periods and is not indicative of annual production.

Table 3. Reproductive summary of white-tailed jackrabbits in South Dakota, 2004 and 2005.

Year	Littering Period	n*	Mean Litter Size	Range	Viable Fetuses	Ova Shed	Resorption	Prenatal Mortality
2004	3	8	5.5	4 to 8	40	41	1	2%
	4	3	5	4 to 7	15	15	0	0%
	1	13	4.2	1 to 7	54	79	2	32%
2005	2	4	6	5 to 8	24	25	1	4%
	3	7	4.7	3 to 6	33	35	1	6%
	4	2	3	3	6	7	0	14%

*Number gravid females.

CHAPTER 4. CAPTURE METHODS AND HOME RANGE SIZE OF WHITE-TAILED JACKRABBITS WITHIN SELECTED FIELDS IN EASTERN SOUTH DAKOTA

INTRODUCTION

White-tailed jackrabbits inhabit short-grass prairie where they fill an important niche throughout the Northern Great Plains. While little data exists on the home range of white-tailed jackrabbits, this information may be useful in determining several unknown ecological characteristics. Home range is defined as the area traversed by an individual animal during activities such as mating, feeding, and caring for young (Burt 1943). Jackrabbit home range size depends on and varies with food, cover, and water distribution (Lechleitner 1958, Dunn et al. 1982, Smith 1990).

Few studies have been conducted on white-tailed jackrabbits using radio telemetry and little is known about their activity patterns. Their home range size was reported to average 2.59 km^2 on the Pawnee National Grasslands in Colorado (Donoho 1972). In addition, Rogowitz (1997) used radio telemetry to find that white-tailed jackrabbits in Wyoming demonstrate decreased locomotor activity and increased foraging efforts under snow covered conditions. Rogowitz (1997) also found that low ambient temperature, precipitation, and cloud cover had no significant effect on white-tailed jackrabbit activity, while earlier researchers previously thought these factors affected jackrabbit behavior (Lechleitener 1958, Tiemeier 1965).

Although telemetry research on white-tailed jackrabbits is limited, there have been several research efforts utilizing telemetry on black-tailed jackrabbits. The ability to traverse their entire home range within short periods of time has been reported in several studies on black-tailed jackrabbits (Lechleitner 1958, French et al. 1965, Smith 1990). Estimated home range sizes for black-tailed jackrabbits were 0.20 km^2 in California (Lechleitner 1958), less than 0.16 km^2 in Idaho (French et al. 1965), and 0.18 km^2 in Nebraska (Plettner 1984). Smith (1990) reported that black-tailed jackrabbit home ranges varied from less than 1.0 km^2 to 3.0 km^2 in Utah.

Differences between sexes in jackrabbit home range size have been variable among studies. Male white-tailed jackrabbits were found to have a larger home range size than females in Colorado (Donoho 1972). Female black-tailed jackrabbits in California seasonally use larger areas than males (Lechleitner 1958). Some researchers have reported that no significant difference exists in black-tailed jackrabbit home range size between sexes (Tiemeier 1965) or seasons (Smith 1990).

Seasonal movements have been documented in many black-tailed jackrabbit populations and may influence home range and habitat use estimates. Movements of hares are likely in response to weather or food availability (Lechleitner 1958). Flinders and Hansen (1972) reported that black-tailed jackrabbits in northeastern Colorado move from alfalfa fields during winter to short-grass prairie in spring. Plettner (1984) found that black-tailed jackrabbits in east central Nebraska utilized pasture and corn fields during winter. Extended movements have also been reported in some black-tailed jackrabbit populations. In Utah, Porth (1995) found that long distance movements of black-tailed jackrabbits during the fall may approach 12 km. Although long distance movements are important in understanding wildlife populations, few reports of extensive movements exist for jackrabbits (Smith et al. 2002).

Habitat quality may create the need for daily movements which may also influence home range size of jackrabbits. Since some habitats offer both food and resting cover, movement of hares between diurnal and nocturnal areas may be minimal (Donoho 1972). Other habitats may have limited resources that jackrabbits are able to utilize. Concentrations in isolated areas may occur as a result of movements during feeding or inclement weather (Donoho 1972).

OBJECTIVES

Little research has been conducted on hares in South Dakota and there is a paucity of information on the home range of white-tailed jackrabbits throughout their range. Radio telemetry research efforts were focused on white-tailed jackrabbits in eastern South Dakota with the following objectives; (1) evaluate capture methods, (2) estimate home range size, (3) identify general habitat use and, (4) determine causes of mortality. This data is intended to provide managers with baseline information concerning white-tailed jackrabbit ecology in South Dakota.

STUDY AREA

White-tailed jackrabbits were monitored using radio telemetry on four sites in Brookings, Kingsbury, and Beadle Counties in eastern South Dakota. To increase probability of capture, I selected study sites where numerous white-tailed jackrabbits were present. Telemetry sites were also selected based on road accessibility and permission from landowners.

The first two sites collectively occupied approximately 129 ha (320 acres) near Brookings, South Dakota. Brookings County lies within the Big Sioux Basin, a level IV ecoregion described by Bryce et al. (1998). This region annually receives 51-56 cm (20-22 in) of precipitation. Daily high temperatures range from 6 to 29° C (22 to 85° F) throughout the year. Natural vegetation includes tall-grass prairie flora such as big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), and indiangrass (*Sorghastrum nutans*). Land use within this region is typically agricultural with the primary crops being small grains, corn and soybeans. The specific telemetry sites used in Brookings County serve as soil testing grounds for agricultural crops and are managed by the South Dakota Agricultural Experiment Station. These locations have been known sanctuaries for white-tailed jackrabbits as they have historically created depredation problems for agricultural experiments. Due to similarity in land use as well as their proximity, both fields are referred to as the same site (Brookings).

The third study site was located in Kingsbury County near De Smet, South Dakota, and the fourth study site was located in Beadle County near Huron, South Dakota. Both areas consisted of 259 ha (640 acres) of pasture used primarily for grazing. Cattle frequented these areas in summer but were absent in winter. Grazed pastures were located on all sides, but cultivated land was within 0.08 km to 1.6 km of the study sites. The Kingsbury and Beadle sites are located within the James River Lowland, a level IV ecoregion described by Bryce et al. (1998). This area receives 46-51 cm (18-20 in) of annual precipitation and average daily high temperatures range from 6 to 31° C (22 to 87° F) throughout the year. Natural vegetation includes western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Stipa viridula*), big bluestem and blue grama (*Bouteloua gracilis*). Land use is typically agricultural with the dominant crops being wheat, corn, and soybeans.

METHODS

Trapping and Collar Attachment

White-tailed jackrabbits were captured using double-door live traps manufactured by Tomahawk Live Traps Co. (Tomahawk, WI). Each trap measured 106.7 cm (42 in) in length with an opening of 38.1x38.1 cm (15x15 in). Traps were set within areas utilized by jackrabbits as evidenced by trails, feces, and or physical observations (Plettner 1984). Bait used to attract jackrabbits included carrots, alfalfa, potatoes, tomatoes, and apples.

Since trapped jackrabbits tend to violently jump against trap walls, I attempted to minimize injury of captured jackrabbits by covering the trap with a blanket to calm the animal as recommended by Plettner (1984). Once the captured animals were tranquil, I removed them from the trap, placed them in a bag, and determined gender from external genitalia. Radio collars were then attached and the animal was released.

Due to a low capture rate during months without snow cover, I attempted alternative trapping methods including night-lighting (Griffith and Evans 1970) and a drive corral (Henke and Demarais 1990). Capture efforts were focused on the drive corral method after night-lighting was determined to be ineffective for white-tailed jackrabbits in our selected study sites. The drive corral consisted of nylon netting fixed to four 2.4x1.5-m (8x5-ft) panels, three of which served as the corral walls and one acted as a wing gate. The entrance of the corral was approximately 3.7 m wide. A funnel was created using lead lines of poultry wire with 7.6 cm (3 in) square mesh that extended for 137 m (150 yards) in a 45° angle from the opening of the corral. Telemetry sites were large (129 to 259 ha), so I could not use field assistants for drivers (Henke and Demarais 1990) as jackrabbits would easily escape. Instead, two ATV's were driven in a zig-zag formation to flush jackrabbits and direct them toward the corral. When a jackrabbit entered the corral, a person hidden near the entrance would close the gate. The corral walls were then aligned to reduce jackrabbit movements within the corral. Jackrabbits were captured by hand and placed into a bag and then fitted with a radio collar.

Trapping rates were calculated by dividing the number of animals captured by the number of individual traps. Capture rate for the drive corral was measured by dividing the number of jackrabbits captured by the number of individual corralling attempts. In order to compare capture efforts between the two methods, capture rate was also calculated by dividing the number of captures by the number of man-hours spent trapping.

Telemetry Equipment and Monitoring

VHF transmitters were manufactured by Advanced Telemetry Systems, Inc. (Isanti, MN). Collars were designed with nylon to reduce skin irritation (Wywialowski and Knowlton 1983) and attached with a double-fastener (Bond et al. 2000). The antenna exited the transmitter at a 40° - 60° angle to prevent the jackrabbit from chewing the antenna. Transmitters had frequencies within the 150 and 151 MHz range and a pulse rate of 40 ppm. Each transmitter was designed to have a 12-hour duty cycle and had a battery life of approximately 19 months. Transmitters were also equipped with a mortality sensor. I activated the transmitters at approximately 1200 hours which permitted them to function until 2400 hours allowing me to obtain daily and evening locations. Each radio collar weighed 35 grams, which is approximately 1% of the weight of an adult jackrabbit.

Radio-collared jackrabbits were monitored from January to December 2005 by triangulation using the program LOCATE. I used a 4-element null peak antenna system mounted on the roof of a 4-wheel drive pickup. Occasionally jackrabbits were manually tracked using a handheld 3-element yagi antenna to make direct visual observations. This method allowed me to obtain the location of an individual's form with a handheld GPS unit. Specific habitat use and flushing distance were also recorded for each jackrabbit. I attempted to obtain locations of all radio-collared jackrabbits from either source of monitoring at least once a week at all three telemetry sites.

When mortality signals were observed, the manual tracking method served as a means to investigate and collect any causal evidence. Investigative methods suggested by Mech (1967) were used to determine the cause of any confirmed mortalities. When assessing mortality, I attempted to determine if a predator killed the animal, or if it was scavenged, by searching for predator tracks or droppings and evidence of struggle (Stoddart 1970). Evidence of avian predation may include only skeletal remains, hair strewn about, and presence of avian excreta (Stoddart 1970).

Data Analysis

Home range size was measured using the fixed kernel estimator with the reference or optimal smoothing parameter as the bandwidth. Radio telemetry datasets rarely conform to a regular distribution, therefore a nonparametric estimator is generally preferred (Kernohan et al. 2001). I defined the home range size as the 90% contour of utilization and the core area as the 50% contour of utilization. The 95% minimum convex polygon (MCP) estimator was also calculated for comparison among studies. All analyses were accomplished using the Home Range Extension (HRE) for ArcView® 3.2. Two-sample t-tests were used to detect differences in home range size between sexes and between telemetry sites ($\alpha = 0.05$).

RESULTS

Brookings

A total of 12 white-tailed jackrabbits (six males, six females) was captured and fitted with radio collars at the Brookings telemetry site. Eight jackrabbits (three males, five females) were captured using the drive corral, and four (three male, one female) were caught in live traps. Approximately six hours were spent in four corralling attempts, resulting in 1.3 jackrabbits captured per man-hour. There were 252 traps set over 21 nights resulting in 0.02 jackrabbits captured per trap-night. Twenty-six hours were spent setting and checking traps resulting in 0.15 jackrabbits captured per man-hour (Table 1).

Home range size was estimated for four males and four females (Table 2). The average male (0.63 km^2) and female (0.59 km^2) home range size did not significantly differ ($p = 0.86$). Location sample size for all individuals ranged from 18-38 locations and averaged 26 per animal. Overall home range size was 0.61 km^2 for both sexes. During manual tracking of jackrabbits, 80 observations of forms were recorded with 64 forms in cultivated land and 16 forms in grassland habitat.

Kingsbury

A total of 12 white-tailed jackrabbits (six males, six females) was captured and fitted with radio collars at the Kingsbury telemetry site. Six jackrabbits (four males, two females) were captured using the drive corral, and six (two males, four females) were caught in live traps. Approximately 18 hours were spent in six corralling attempts, resulting in 0.33 jackrabbits captured per man-hour. There were 105 traps set over 11 nights, resulting in 0.06 jackrabbits captured per trap-night. Setting and checking traps took approximately two hours each time resulting in 0.27 jackrabbits captured per man-hour (Table 1).

Home range size was calculated for four females and all six males (Table 2). The average male (2.16 km^2) and female (1.78 km^2) home range size did not significantly differ ($p = 0.65$) (Table 2). Sample size for all individuals ranged from 22-66 locations and averaged 46 per collared jackrabbit. Overall home range size was 2.00 km^2 for both sexes. There were 156 observations from manually tracked radio collared jackrabbits with 146 forms in grassland and 10 forms in cultivated land.

Beadle

A total of 10 white-tailed jackrabbits (seven males, three females) was captured and fitted with radio collars at the Beadle telemetry site. Two jackrabbits (both male) were captured using the drive corral, and eight (five males, three females) were caught in live traps. Approximately nine hours were spent in three corralling attempts, resulting in 0.22 jackrabbits captured per man-hour. There were 116 traps set over nine nights resulting in 0.07 jackrabbits captured per trap-night. Setting and checking traps took approximately 1.5 hours per attempt resulting in a 0.59 jackrabbits captured per man-hour (Table 1).

Home range size was estimated for five males and two females (Table 2). Average home range size did not significantly differ between male (0.94 km^2) and female (0.75 km^2) jackrabbits ($p = 0.33$) (Table 2). Sample size for all individuals ranged from 15-29 locations and averaged 23 per animal. Overall home range size was 0.88 km^2 for both sexes. Triangulation was the only monitoring method used at this site.

Overall

A total of 34 white-tailed jackrabbits was captured at all three telemetry sites. There were 18 jackrabbits captured using live traps and 16 jackrabbits captured using the drive corral (Table 1). Of these captures, there were 25 individuals with adequate sample size to estimate home range size (Table 2). I was unable to obtain enough locations to estimate home range size for the remaining nine jackrabbits due to mortality, collar failure, or an unknown cause.

Between sites, male white-tailed jackrabbit home range size at the Kingsbury site (2.16 km^2) was significantly different from males at the Brookings site (0.63 km^2) ($p = 0.05$), but did not significantly differ from males at the Beadle site (0.94 km^2) ($p = 0.09$). Male home range size was not significantly different between the Beadle and Brookings sites ($p = 0.33$).

Female home range size estimated at the Kingsbury site (1.78 km^2) was not significantly different from females at the Brookings site (0.59 km^2) ($p = 0.12$) or the Beadle site (0.75 km^2) ($p = 0.17$). Similarly, female home range size at the Brookings site did not significantly from the Beadle site ($p = 0.27$).

Average home range size for both sexes was largest at the Kingsbury telemetry site (2.00 km^2), and smallest at the Brookings telemetry site (0.61 km^2). Home range sizes were significantly larger at Kingsbury than Brookings ($p = 0.01$) and Beadle ($p = 0.02$). No significant difference in home range size was detected between Brookings and Beadle ($p = 0.14$). The average female (1.09 km^2) and male (1.34 km^2) home range size did not significantly differ among the three telemetry sites ($p = 0.54$).

Causes of Mortality

Mammalian predators were identified as the only source of jackrabbit mortality during this project. Three jackrabbits were likely killed by a coyote (*Canis latrans*) as evidenced by tracks near the kill. Impressions from canines were also left on the transmitters and remains of the hares were scattered. On two occasions, there was a visible trail through the vegetation leading to the remains of the collared hare.

Two radio collared jackrabbits were found approximately six inches underground. The remains were cleanly sectioned and appeared to be cached suggesting these jackrabbits were killed by a red fox (*Vulpes vulpes*). I could not determine the cause of death for three jackrabbits that had been killed or scavenged. There were also five radio collars that I was unable to account for.

DISCUSSION

Trapping Methods

Live traps performed well at all study sites, especially in winter months with snow cover. However, capture rates using live traps decreased markedly during spring and summer. Donoho (1972) also experienced seasonal differences in trapping success attributing a high fall success rate to increased population size and dying of vegetation which made bait more attractive. Of the bait types used, I found that moist, rotten apples worked best for enticing jackrabbits into traps. Several non-target species, such as striped skunks (*Mephitis mephitis*), badgers (*Taxidea taxus*), opossum (*Didelphia marsupialis*), woodchuck (*Marmota monax*), and raccoons (*Procyon lotor)* were also captured when apples were used as bait. Skunks pose the largest problem as their scent seemed to attract more skunks to the trap in which the original animal was captured.

The drive corral worked well in all seasons and was an effective alternative to live traps. The drive corral method should be used in areas of open terrain which is free from obstacles. At the Beadle County site, the drive corral was difficult to utilize because high amounts of ruts and rocks made maneuvering the ATV difficult and dangerous. The topography of potential trapping fields should be evaluated prior to use of the drive corral.

Injuries sustained by captured jackrabbits using live traps were similar to those observed by Mech (1967) and Plettner (1984). Prior to covering the trap with a blanket, the jackrabbit would violently jump against the trap walls causing injury to the face and flanks. These injuries cannot be completely avoided but are minimized if the blanket is used immediately after discovery of the trapped animal. Fewer jackrabbit injuries occurred in the drive corral because the nylon trap walls reduced impact from jumping after capture.

The physiological condition of corralled jackrabbits must be considered before attaching the radio collar. Most corralled jackrabbits were panting heavily after capture, so the holding bag was maneuvered to cover their eyes but leave the nose and mouth exposed. By providing the animal with fresh air, I was able to avoid asphyxiating captured jackrabbits and ensured them adequate oxygen during the transmitter attachment process.

Transmitter Design and Monitoring Methods

The radio collar was designed following suggestions from Bond et al. (2000) and Wywialowski and Knowlton (1983) and was well suited for white-tailed jackrabbits in eastern South Dakota. I recommend using a collar length of 12.7-17.8 cm (5-7 in) for white-tailed jackrabbits since it will fit both juveniles and adults.

Although jackrabbits were manually tracked to obtain specific habitat data, triangulation was the preferred method since there was no disturbance to the animal. During manual tracking, average flushing distance of hares remained fairly consistent and I assume any effect on their normal movements was negligible. Since monitoring was conducted at varying times during day and night, methods of obtaining locations allowed for independent observations thereby reducing any effects of autocorrelation (Kernohan et al 2001).

Home Range and Habitat Use

Overall, estimated jackrabbit home ranges did not significantly differ between sexes across telemetry sites. However, jackrabbit home range sizes were significantly smaller at the Brookings and Beadle sites than at the Kingsbury site. Since the Kingsbury site was predominately grassland, jackrabbits may have needed larger home ranges to find sufficient food resources and cover. The availability of high quality food and shelter within agricultural fields may limit the need for jackrabbits to make long distance movements.

Average home range estimates for white-tailed jackrabbits were smaller than those reported by Donoho (1972) in Colorado (2.59 km^2) in the Pawnee National Grasslands. The most similar home range estimates from this study were at the Kingbury site (2.0 km^2), which is also primarily grassland habitat. White-tailed jackrabbit home range size in eastern South Dakota appears larger than most reported home ranges for black-tailed jackrabbits. Although variations exist, analytical and procedural differences have made comparisons of home range size among studies difficult (Donoho 1972, Smith 1990).

Habitat use determined from manual tracking varied between the Brookings and Kingsbury telemetry sites. Jackrabbits utilized cultivated land for 80% of the observations and grassland for 20% of the observations at the Brookings site. In Kingsbury, 6% of observations were in cultivated land and 94% were in grassland. Since Brookings is mostly cultivated land and Kingsbury is mostly grassland, it appears that jackrabbits demonstrate opportunistic habitat selection. There were no manual tracking data from the Beadle telemetry site.

Utilization of forms during daylight is common among leporids (Vorhies and Taylor 1933, Lechleitner 1959, Smith 1990). Most radio-collared jackrabbits were observed in a form; however, I observed several jackrabbits using underground burrows. This behavior has also been noted in jackrabbits by Vorhies and Taylor (1933) in Arizona and by Smith (1990) in Utah. Daily use of burrows has not been reported as a life history trait, although this behavior may be in response to inclement weather and/or predation (Smith 1990).

Causes of Mortality

Since there was no evidence of avian predation, it appeared that mammalian predators were the only source of jackrabbit mortality during this project. Several researchers have reported that mammalian predators have the most impact on jackrabbit populations. In Utah, jackrabbits were estimated to comprise nearly 75% of coyote diet (Clark 1972, Stoddart 1970). Red fox and gray fox (*Urocyon cinereoargentens*) are significant jackrabbit predators in the mid-west (Errington 1935). Wagner and Stoddart (1972) report that bobcats may be a significant predator, but of lesser importance than coyotes. Evans et al. (1970) reported that predators had a limited role in regulating jackrabbit populations in agricultural habitats.

There were two instances where a chase was identified by patterns in the vegetation that lead to jackrabbit remains. Given the height of the vegetation, it may be advantageous for a mammalian predator to chase a hare into tall vegetation, inducing panic and increasing probability of capture.

Mech (1967) and Plettner (1984) observed instances where jackrabbit remains appeared cached. The predator was also determined to be a red fox. In addition, there were a few radio collars that could not be found. Stoddart (1970) found that loss of radio collar signals may result from transmitter failure, movement of the animal beyond receiving range, or removal of the transmitter by an outside source such as a predator.

FUTURE RESEARCH

This research provided an estimate of white-tailed jackrabbit home range size and general habitat use within selected fields in eastern South Dakota. Since little is known about white-tailed jackrabbit home range, a more elaborate research design with greater sample sizes should be initiated to compare with our estimated home range sizes. Seasonal movements and survival rates of jackrabbits should be investigated to determine habitat quality and better understand habitat selection. This information may also provide insight to jackrabbit population fluctuations during peak carrying capacity.

Land use may influence fluctuations in white-tailed jackrabbit populations. Grazing by cattle is a form of disturbance that may affect jackrabbit habitat suitability since white-tailed jackrabbits tend to select upland habitats that are sparsely vegetated (Flinders and Hansen 1975). Effects of grazing, prescribed burns, and agriculture on white-tailed jackrabbits should be researched to determine responses and survival rates in cultivated and grassland habitats in South Dakota.

From anecdotal reports, predator control remains a high priority for ranchers in northwest South Dakota. Future research should be conducted to determine how much influence coyote removal has on jackrabbit populations in this area. In addition, coyote removal may suggest an increase in compensatory predator populations when an abundant food source such as jackrabbits are available. Surveys should be conducted to determine the current effects of fox, bobcat, and raptors on jackrabbit populations in northwest South Dakota.

Table 1. Capture rates of white-tailed jackrabbits in selected fields within three eastern South Dakota counties, 2005.

Method		Brookings	Kingsbury	Beadle	Avg
Live Traps	Captured Jackrabbits	4	6	8	6
	Captures/Trap-Night*	0.02	0.06	0.07	0.04
	Captures/Man-Hours**	0.15	0.27	0.59	0.29
Drive Corral	Captured Jackrabbits	8	6	2	5.3
	Captures/Trap-Attempt***	2	1	0.67	1.23
	Captures/Man-Hours**	1.3	0.33	0.22	0.48

*Measured as animals captured / total traps set.
**Calculated by animals captured / hours spent trapping/corralling.
***Calculated as animals captured / number of corralling attempts.

Table 2. Estimated home range size (km^2) of white-tailed jackrabbits within selected fields in eastern South Dakota 2004, 2005. The 90% contour of utilization represents home range size and the 50% contour of utilization represents the core range. The 95% minimum convex polygon (MCP) is also reported for comparison.

			Fixed Kernal Contour of Utilization		
Study Site	Gender	n	90%	50%	95% MCP
Brookings	Male	4	0.63 ±0.23	0.20 ±0.07	0.26 ±0.07
	Female	4	0.59 ±0.12	0.17 ±0.03	0.25 ±0.07
	Average		0.61 ±0.12	0.18 ±0.04	0.25 ±0.05
Kingsbury	Male	6	2.16 ±0.58	0.50 ±0.11	1.18 ±0.44
	Female	4	1.78 ±0.57	0.44 ±0.15	0.86 ±0.25
	Average		2.00 ±0.40	0.48 ±0.08	1.05 ±0.28
Beadle	Male	5	0.94 ±0.19	0.27 ±0.06	0.40 ±0.10
	Female	2	0.75 ±0.02	0.20 ±0.03	0.34 ±0.02
	Average		0.88 ±0.13	0.25 ±0.04	0.38 ±0.07
Overall	Male	15	1.34 ±0.29	0.34 ±0.06	0.68 ±0.20
	Female	10	1.09 ±0.28	0.28 ±0.07	0.51 ±0.13
	Average		1.24 ±0.21	0.32 ±0.05	0.61 ±0.13

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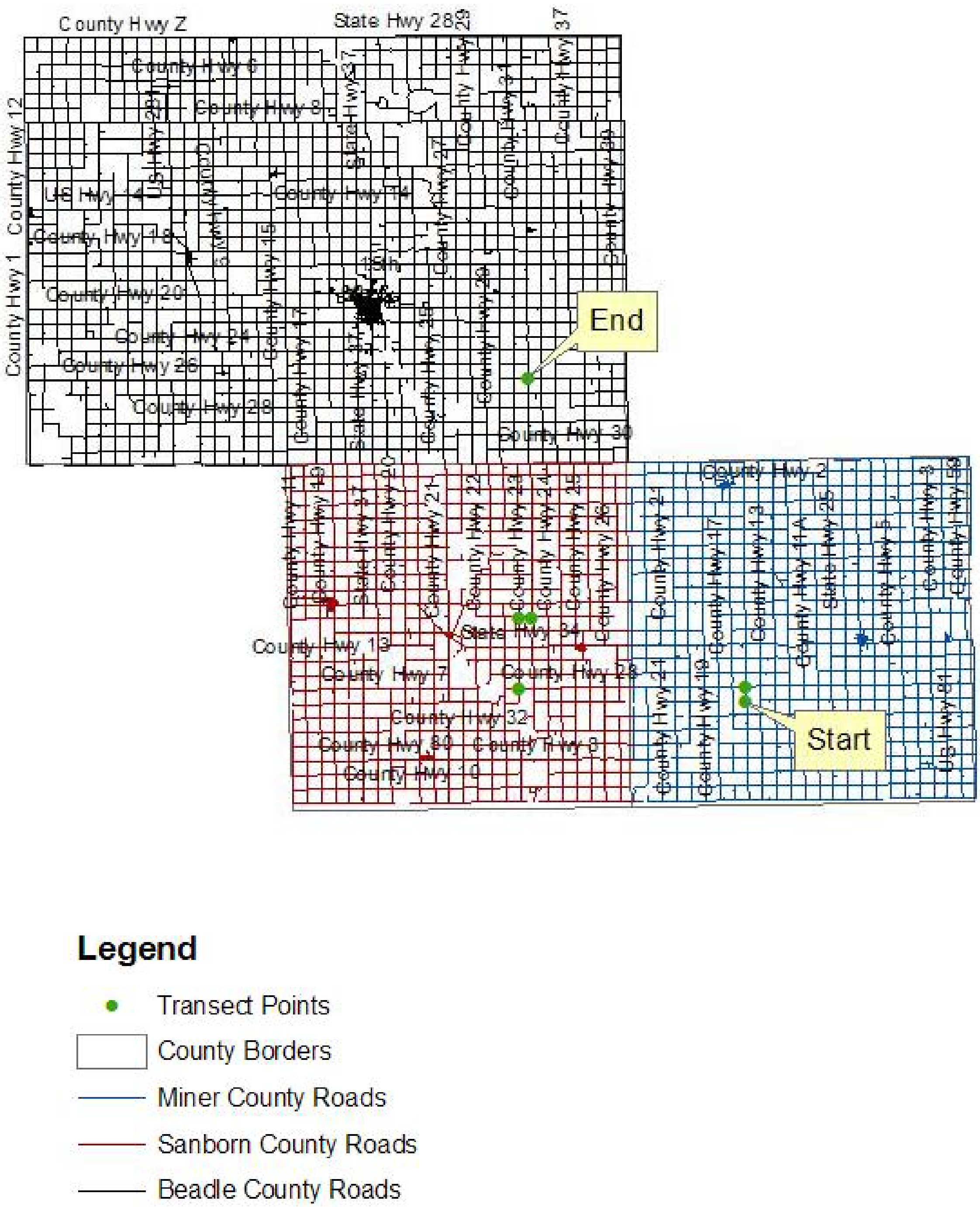
Appendix I. Location of the jackrabbit spotlight survey transect in Beadle, Miner and Sanborn Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	MINER	North	426	237	43.95075	-97.69085	1
1	MINER	West	426	236	43.96526667	-97.69091667	16
2	SANBORN	North	410	236	43.96636667	-98.01113333	5
3	SANBORN	East	410	231	44.03916667	-98.01085	1
4	SANBORN	North	411	231	44.03908333	-97.99086667	17
End	BEADLE		411	214	44.28185	-97.99375	

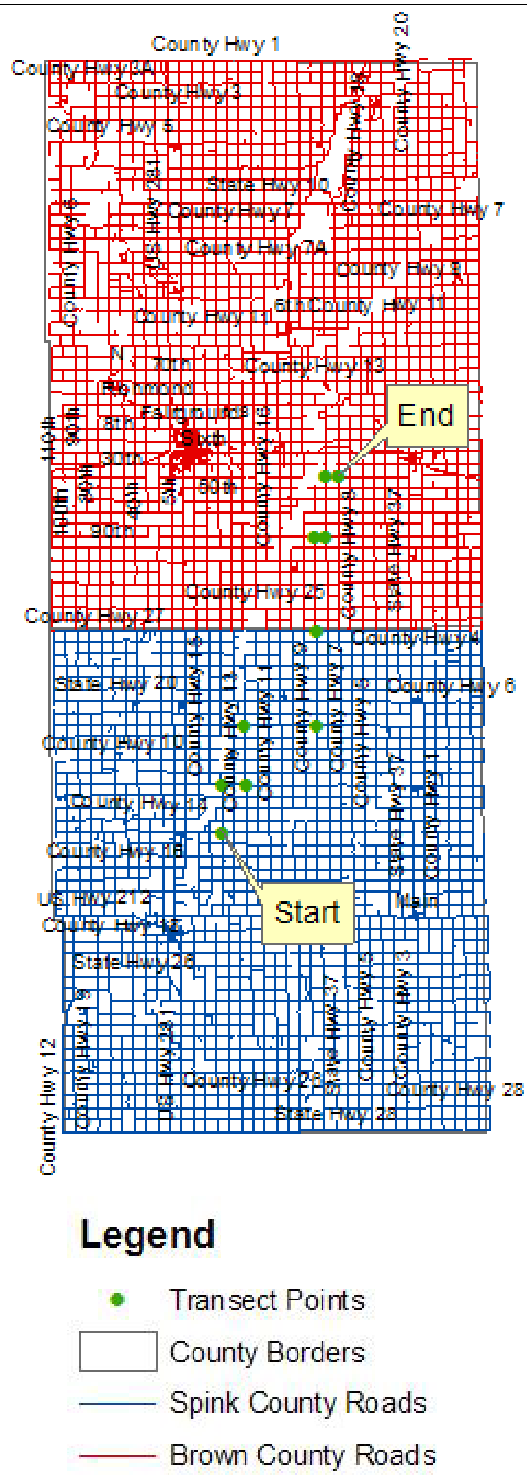
Appendix I con't. Map of the jackrabbit spotlight survey transect in Beadle, Miner and Sanborn Counties in eastern South Dakota.



Appendix I con't. Location of the jackrabbit spotlight survey transect in Brown and Spink Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	SPINK	North	390	165	44.99773333	-98.43186667	4
1	SPINK	East	390	161	45.05563333	-98.43175	2
2	SPINK	North	392	161	45.05498333	-98.39095	5
3	SPINK	East	392	156	45.12785	-98.3909	6
4	SPINK	North	398	156	45.12673333	-98.2683	8
5	SPINK	North	398	148	45.24125	-98.26765	8
6	BROWN	East	398	140	45.35706667	-98.26808333	1
7	BROWN	North	399	140	45.35705	-98.24766667	5
8	BROWN	East	399	135	45.42933333	-98.24723333	1
End	BROWN		400	135	45.42928333	-98.22686667	

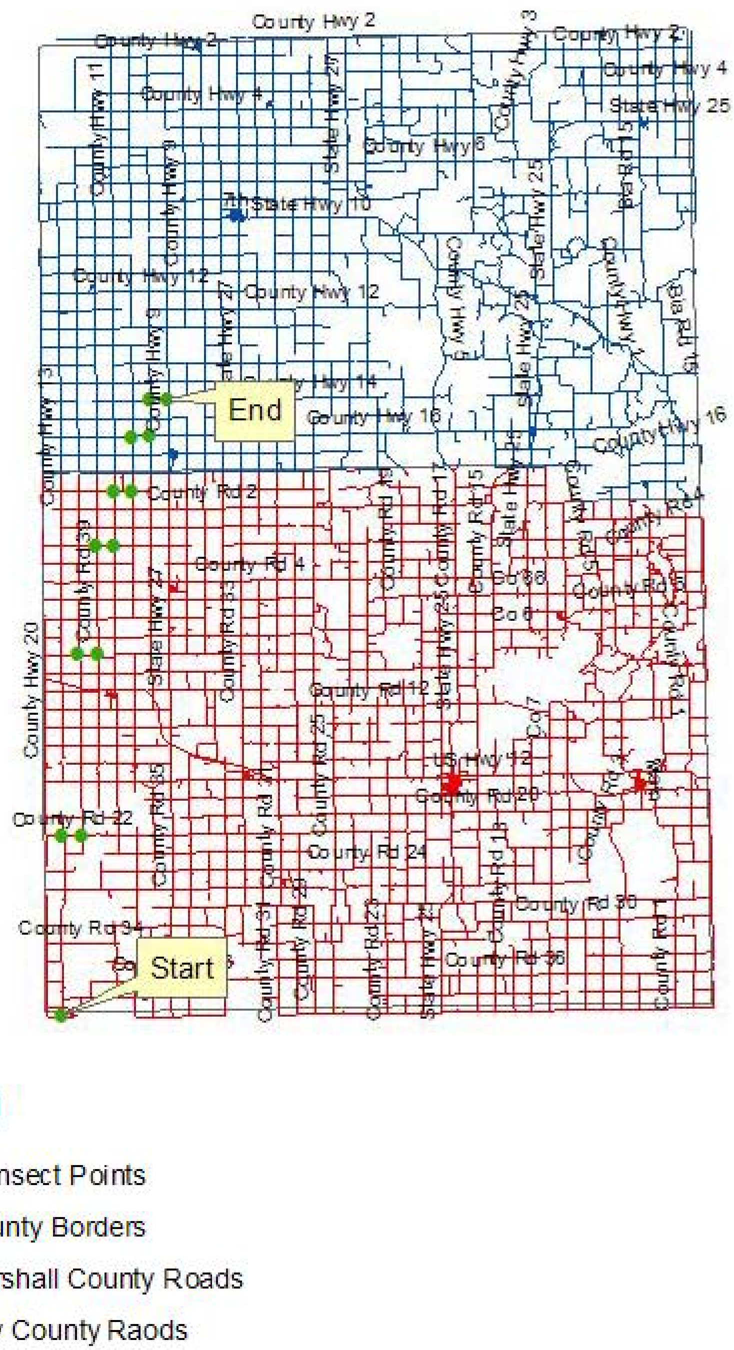
Appendix I con't. Map of the jackrabbit spotlight survey transect in Brown and Spink Counties in eastern South Dakota.



Appendix I con't. Location of the jackrabbit spotlight survey transect in Day and Marshall Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	DAY	North	413	154	45.15311667	-97.96378333	10
1	DAY	East	413	144	45.29826667	-97.9604	1
2	DAY	North	414	144	45.29821667	-97.94001667	10
3	DAY	East	414	134	45.44306667	-97.93988333	1
4	DAY	North	415	134	45.443	-97.91923333	6
5	DAY	East	415	128	45.53005	-97.91841667	1
6	DAY	North	416	128	45.52991667	-97.89781667	3
7	DAY	East	416	125	45.5734	-97.89748333	1
8	DAY	North	417	125	45.57335	-97.87696667	3
9	MARSHALL	East	418	122	45.61715	-97.87621667	1
10	MARSHALL	North	418	122	45.6171	-97.85566667	2
11	MARSHALL	East	419	120ST	45.64608333	-97.85536667	1
End	MARSHALL		419	120	45.64611667	-97.83466667	

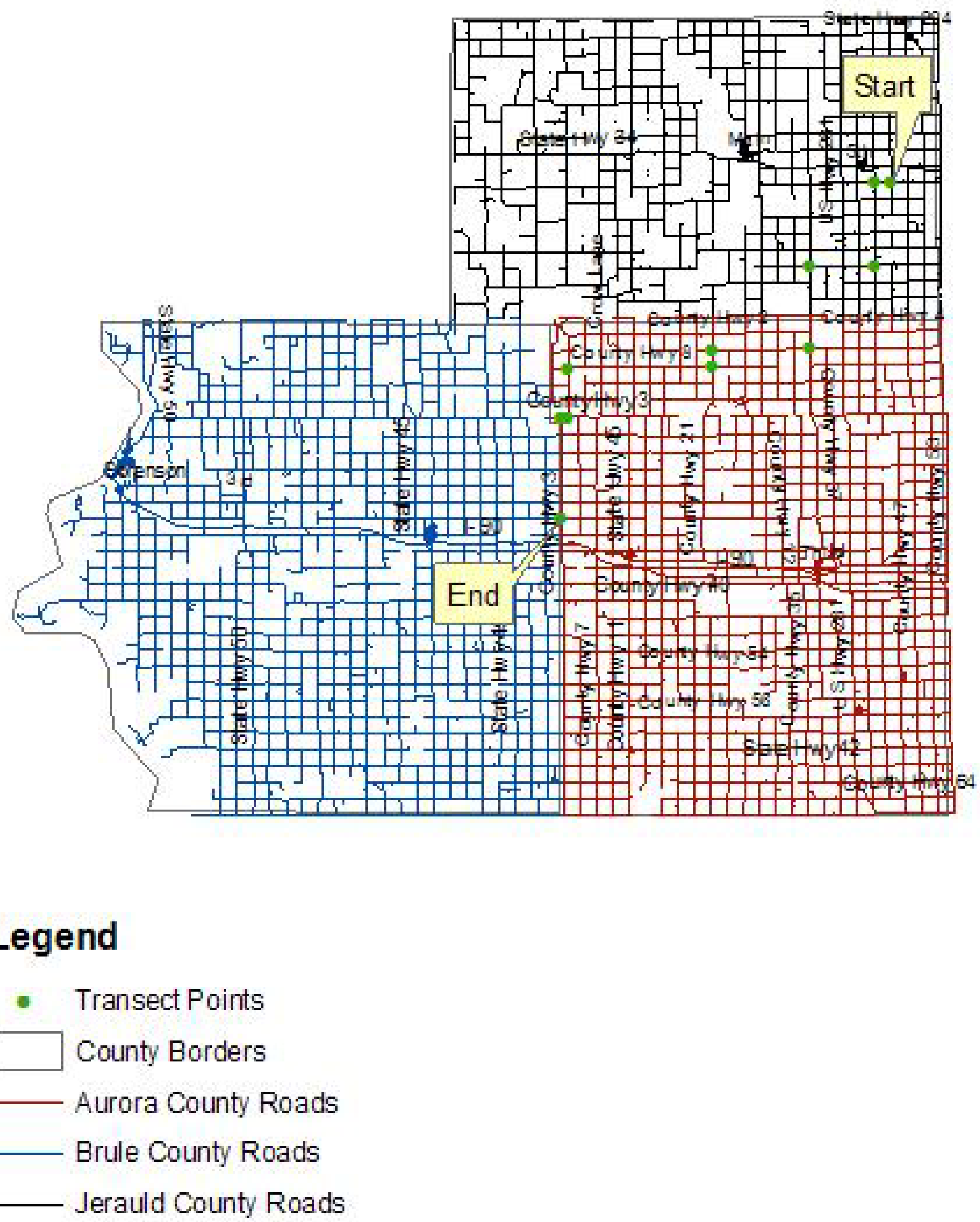
Appendix I con't. Map of the jackrabbit spotlight survey transect in Day and Marshall Counties in eastern South Dakota.



Appendix I con't. Location of the jackrabbit spotlight survey transect in Jerauld, Aurora, and Brule Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	Jerauld	West	391	230	44.0535	-98.39211667	1
1	Jerauld	South	390	230	44.05331667	-98.41211667	5
2	Jerauld	West	390	235	43.98071667	-98.41188333	4
3	Jerauld	South	386	235	43.98028333	-98.49168333	5
4	Aurora	West	386	240	43.90775	-98.49133333	6
5	Aurora	South	380	240	43.90706667	-98.61031667	1
6	Aurora	West	380	241	43.89261667	-98.61038333	9
7	Aurora	South	370	241	43.89208333	-98.78756667	3
8	Aurora	West	370	244	43.84886667	-98.78753333	0.5
9	Aurora	South	370	244	43.84858333	-98.79693333	6
End	Aurora		370	250	43.76021667	-98.79545	

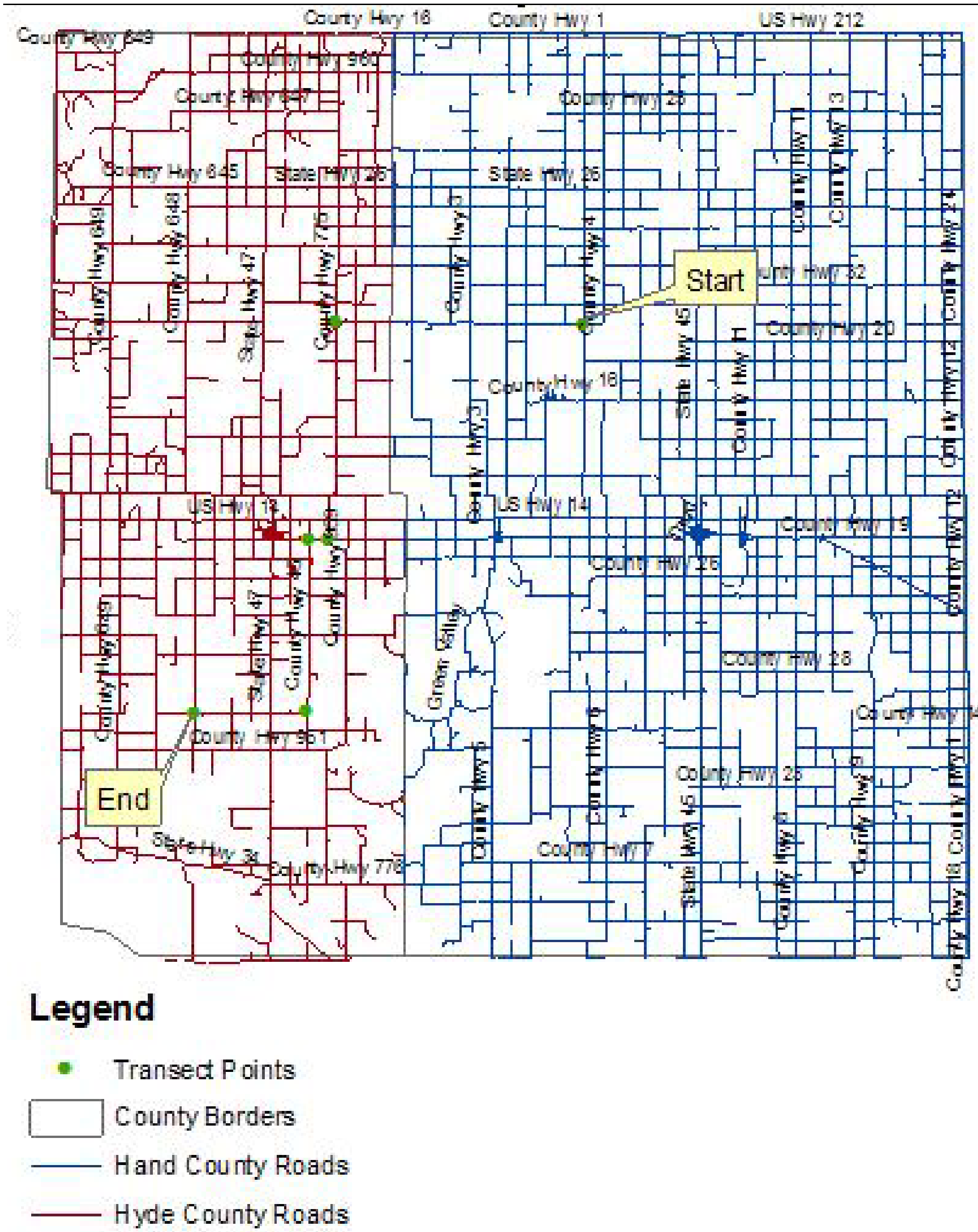
Appendix I con't. Map of the jackrabbit spotlight survey transect in Jerauld, Aurora, and Brule Counties in eastern South Dakota.



Appendix I con't. Location of the jackrabbit spotlight survey transect in Hand and Hyde Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	HAND	West	354	187	44.67803333	-99.10998333	13
1	HYDE	South	340	187	44.67826667	-99.37305	11
2	HYDE	West	340	198	44.51356667	-99.3816	1
3	HYDE	South	339	198	44.51336667	-99.40185	9
4	HYDE	West	339	207	44.38278333	-99.402	6
End	HYDE		333	207	44.38195	-99.52261667	

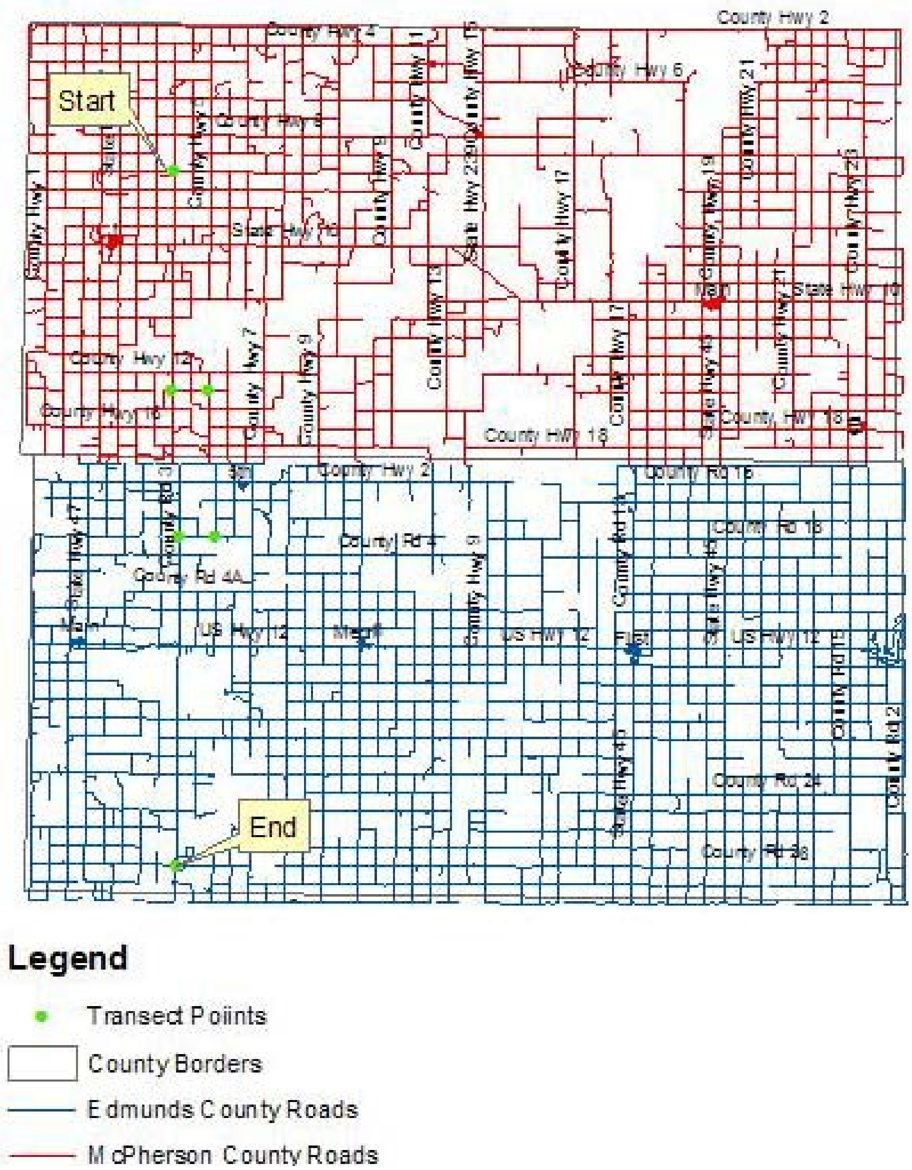
Appendix I con't. Map of the jackrabbit spotlight survey transect in Hand and Hyde Counties in eastern South Dakota.



Appendix I con't. Location of the jackrabbit spotlight survey transect in McPherson and Edmunds Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	MCPHERSON	South	331	108	45.82501667	-99.5523	12
1	MCPHERSON	East	331	120	45.65121667	-99.5523	2
2	MCPHERSON	South	334	120	45.65103333	-99.51091667	8
3	EDMUNDS	West	334	128	45.5354	-99.5024	2
4	EDMUNDS	South	331	128	45.53543333	-99.54368333	16
End	EDMUNDS		331	144	45.2745	-99.54466667	

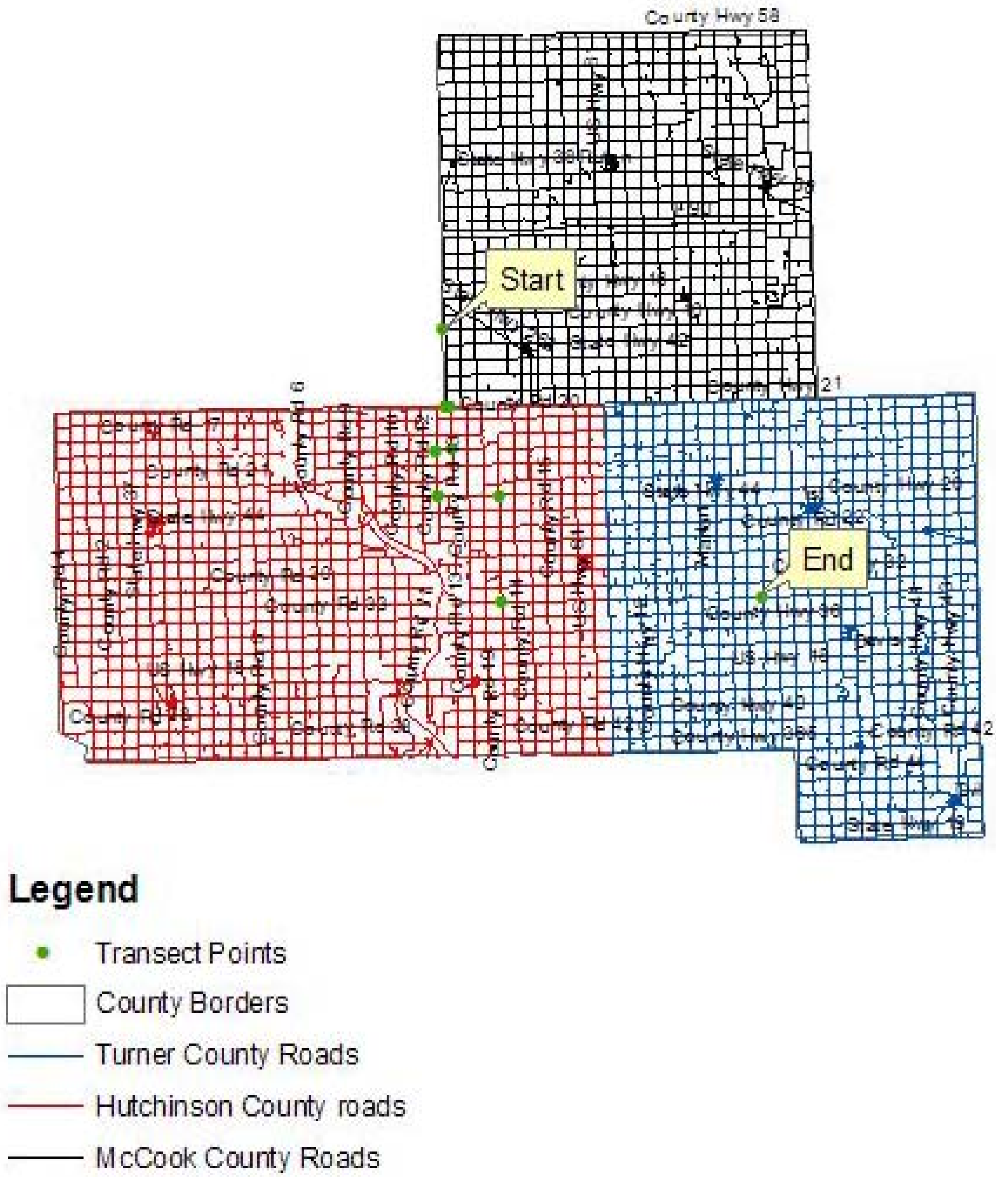
Appendix I con't. Map of the jackrabbit spotlight survey transect in McPherson and Edmunds Counties in eastern South Dakota.



Appendix I con't. Location of the jackrabbit spotlight survey transect in McCook, Hutchinson, and Turner Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	MCCOOK	South	430	263	43.57168333	-97.60688333	5
1	MCCOOK	East	430	268	43.49991667	-97.60703333	0.3
2	MCCOOK	South	430	268	43.49976667	-97.6001	3
3	HUTCHINSON	West	430	271	43.4584	-97.59981667	1
4	HUTCHINSON	South	429	271	43.45818333	-97.61975	3
5	HUTCHINSON	East	429	274	43.41468333	-97.61946667	4
6	HUTCHINSON	South	433	274	43.41481667	-97.54003333	7
7	HUTCHINSON	East	433	281	43.31358333	-97.53958333	17
End	TURNER		450	281	43.31423333	-97.20108333	

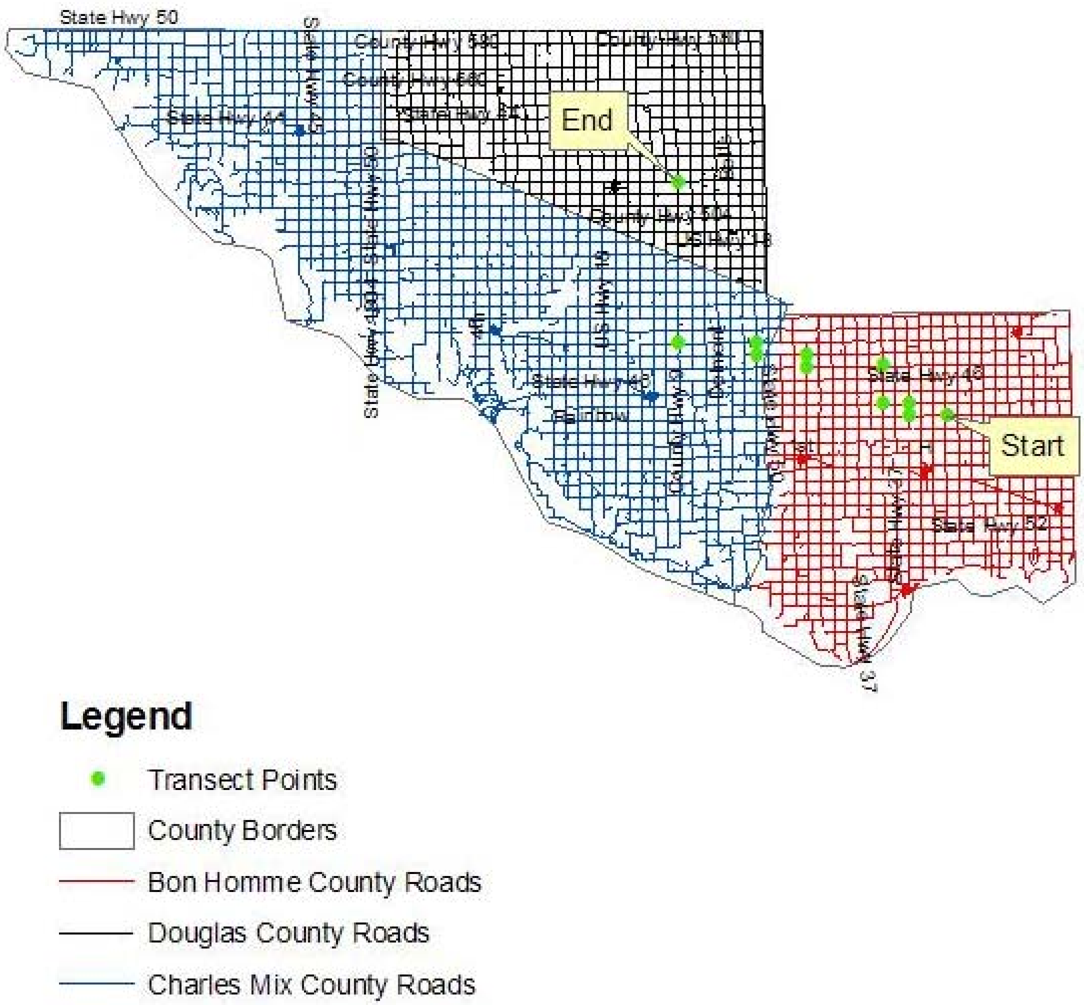
Appendix I con't. Map of the jackrabbit spotlight survey transect in McCook, Hutchinson, and Turner Counties in eastern South Dakota.



Appendix I con't. Location of the jackrabbit spotlight survey transect in Bon Homme, Charles Mix, and Douglas Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	BON HOMME	West	418AVE	299ST	43.05388333	-97.83248333	3
1	BON HOMME	North	415AVE	299ST	43.05365	-97.89115	1
2	BON HOMME	West	415AVE	298ST	43.06805	-97.89115	2
3	BON HOMME	North	413AVE	298ST	43.06793333	-97.93068333	3
4	BON HOMME	West	413AVE	295ST	43.11146667	-97.93058333	6
5	BON HOMME	North	407AVE	295ST	43.11113333	-98.04908333	1
6	BON HOMME	West	407AVE	294ST	43.12541667	-98.04936667	4
7	CHARLES MIX	North	403AVE	294ST	43.12603333	-98.1281	1
8	CHARLES MIX	West	403AVE	293ST	43.14045	-98.1282	6
9	CHARLES MIX	North	397AVE	293ST	43.13951667	-98.24825	13
End	DOUGLAS		397AVE	280ST	43.32555	-98.24658333	

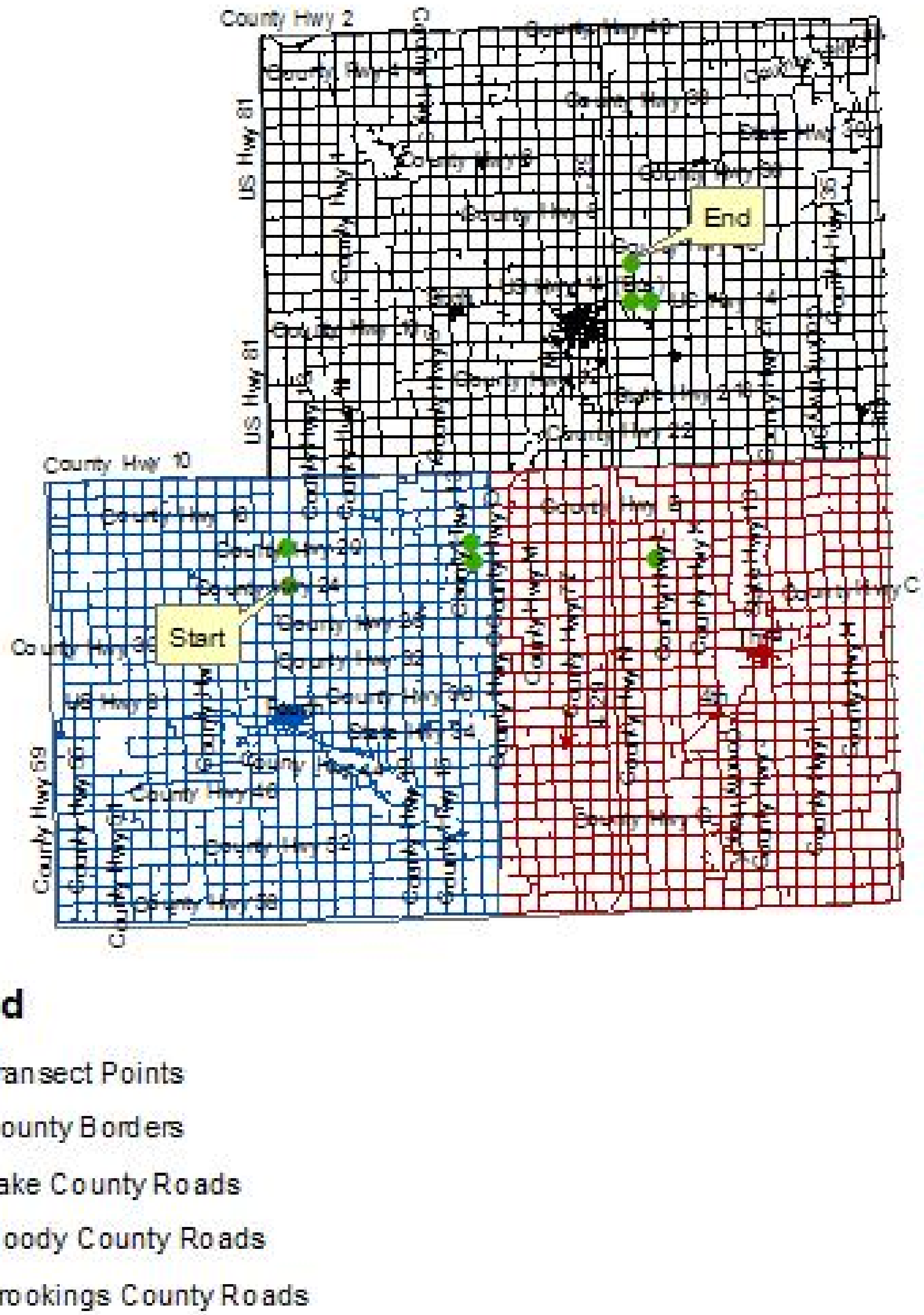
Appendix I con't. Map of the jackrabbit spotlight survey transect in Bon Homme, Charles Mix, and Douglas Counties in eastern South Dakota.



Appendix I con't. Location of the jackrabbit spotlight survey transect in Brookings, Moody and Lake Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	Lake	North	455	226	44.10905	-97.10983333	2
1	Lake	East	455	224	44.13801667	-97.10978333	10
2	Lake	South	465	224	44.13851667	-96.90878333	1
3	Lake	East	465	225	44.12405	-96.90855	10
4	Moody	North	475	225	44.12345	-96.70913333	14
5	Brookings	West	475	211	44.32585	-96.70791667	1
6	Brookings	North	474	211	44.32596667	-96.72818333	2
End	Brookings		474	209	44.35493333	-96.72786667	

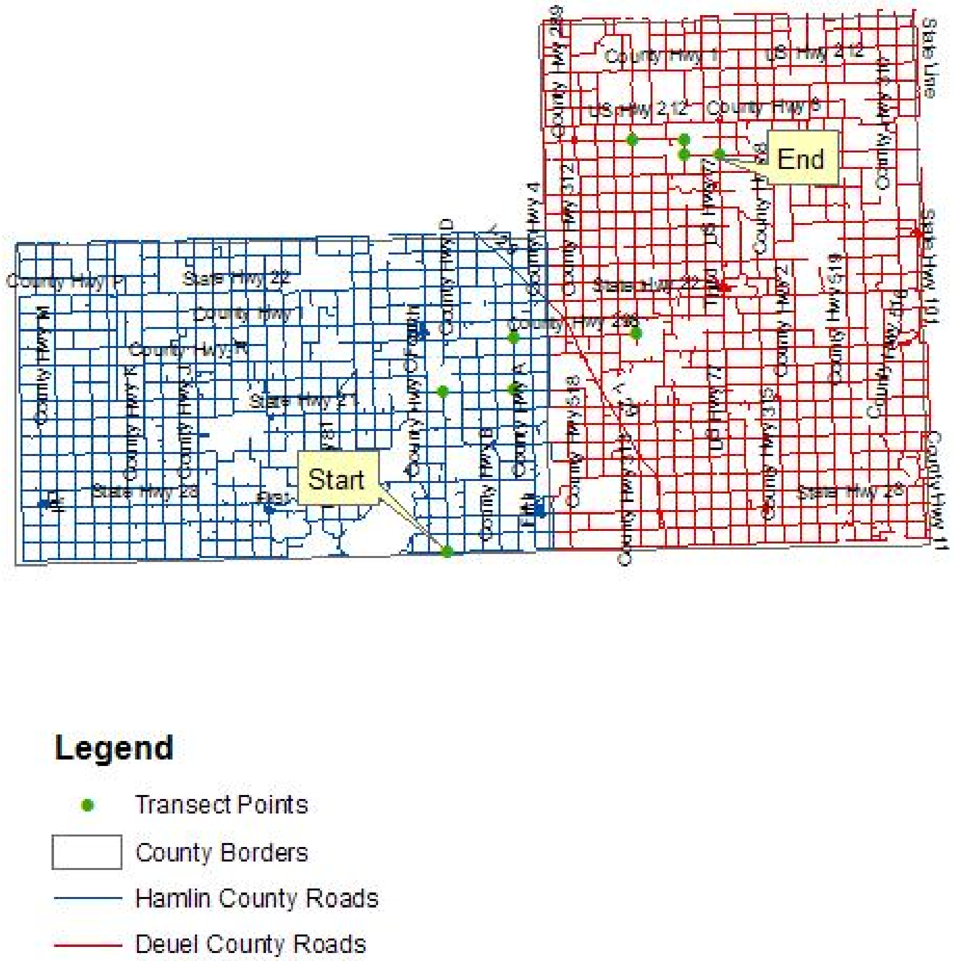
Appendix I con’t. Map of the jackrabbit spotlight survey transect in Brookings, Moody and Lake Counties in eastern South Dakota.



Appendix I con't. Location of the jackrabbit spotlight survey transect in Deuel and Hamlin Counties in eastern South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	HAMLIN	North	460	196	44.54355	-97.00711667	9
1	HAMLIN	East	460	187	44.67383333	-97.00655	4
2	HAMLIN	North	464	187	44.67421667	-96.92581667	3
3	HAMLIN	East	464	184	44.71743333	-96.9252	7
4	DEUEL	North	471	184	44.71748333	-96.78375	11
5	DEUEL	East	471	173	44.87715	-96.78335	3
6	DEUEL	South	474	173	44.87595	-96.72358333	1
7	DEUEL	East	474	174	44.86266667	-96.72336667	2
End	DEUEL		476	174	44.86258333	-96.68261667	

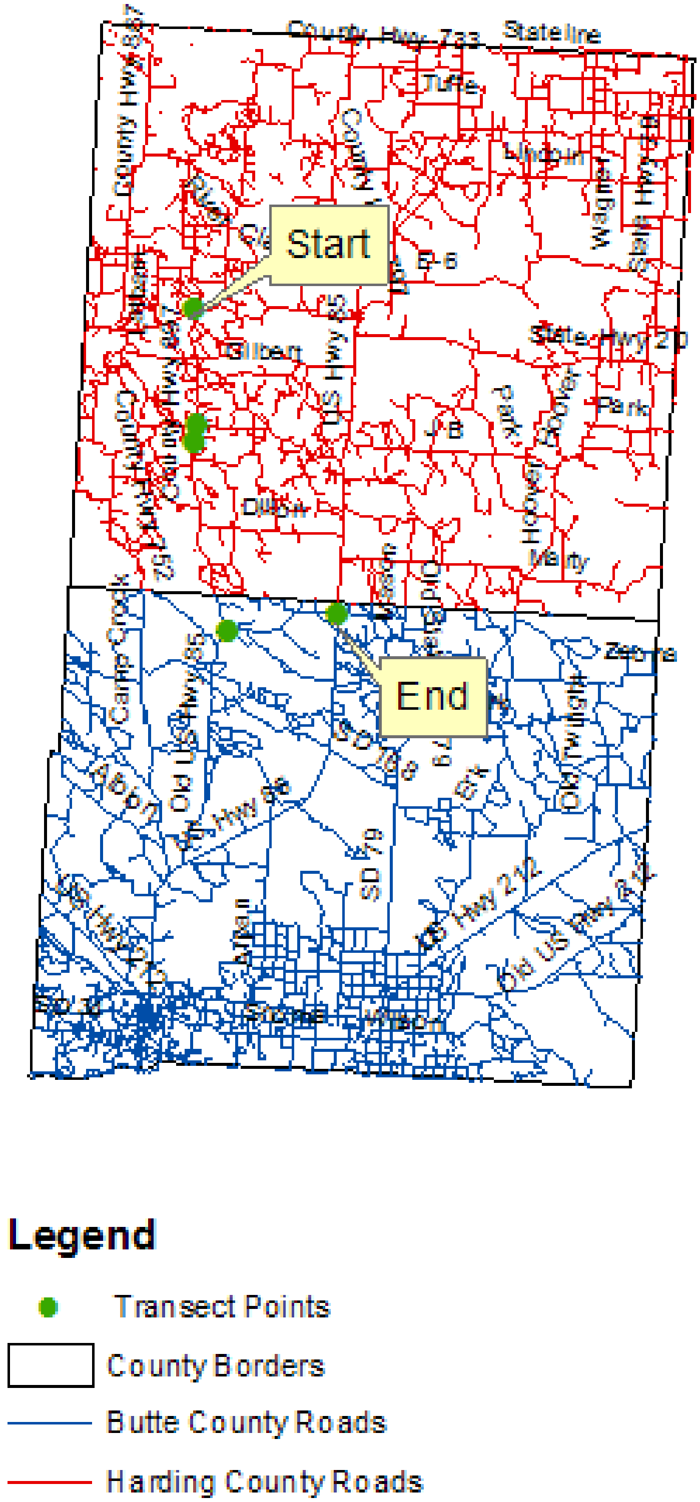
Appendix I con't. Map of the jackrabbit spotlight survey transect in Deuel and Hamlin Counties in eastern South Dakota.



Appendix II. Location of the jackrabbit spotlight survey transect in Harding and Butte Counties in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	HARDING	South	Harding Rd (897)	Hiway 20	45.57846667	-103.8466167	10
1	HARDING	South	Harding Rd (897)	Mackey Rd	45.43258333	-103.8305667	20.5
2	BUTTE	East	Harding Rd (897)	Old Hiway 85	45.1667	-103.7469	10
End	BUTTE		Hiway 85	Old Hiway 85	45.19863333	-103.5486	

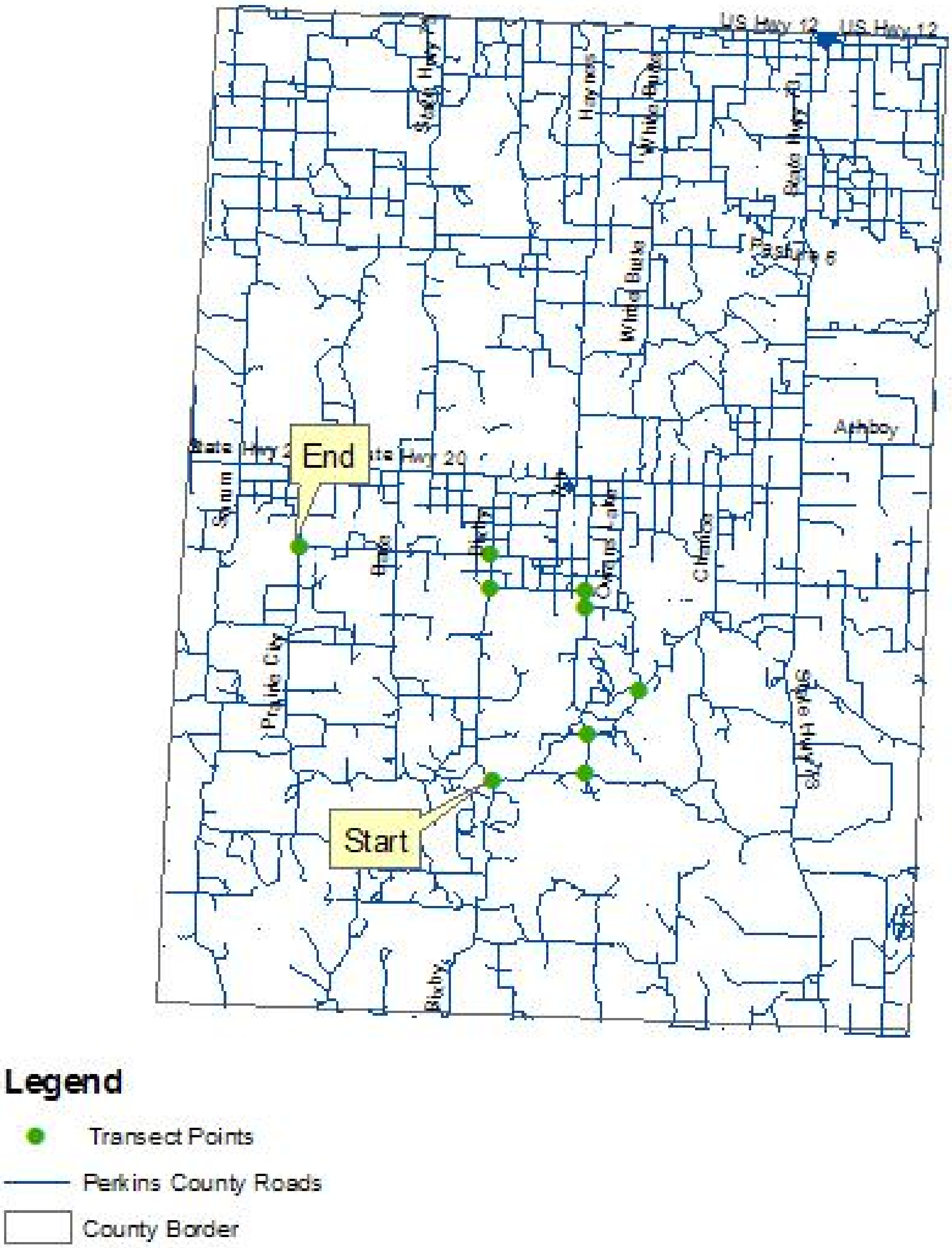
Appendix II con't. Map of the jackrabbit spotlight survey transect in Harding and Butte Counties in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Perkins County in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	PERKINS	East	BIXBY	CR-13	45.25511667	-102.5446167	5.75
1	PERKINS	North	CR-13	CHANCE RD	45.26425	-102.4272	2.5
2	PERKINS	East-NE	CHANCE RD	ADA	45.2997	-102.4263667	4.25
3	PERKINS	North	CR-11	CHANCE RD	45.34203333	-102.3649333	7.5
4	PERKINS	North	CR-11	180AVE	45.41491667	-102.43715	1
5	PERKINS	West	180TH AVE	136TH ST	45.42923333	-102.4371	6
6	PERKINS	North	BIXBY ROAD	136TH ST	45.42938333	-102.5604167	2
7	PERKINS	West	BIXBY ROAD	134 TH ST	45.45843333	-102.5602833	12
End	PERKINS		PRAIRIE CITY RD	134TH ST	45.45866667	-102.8068833	

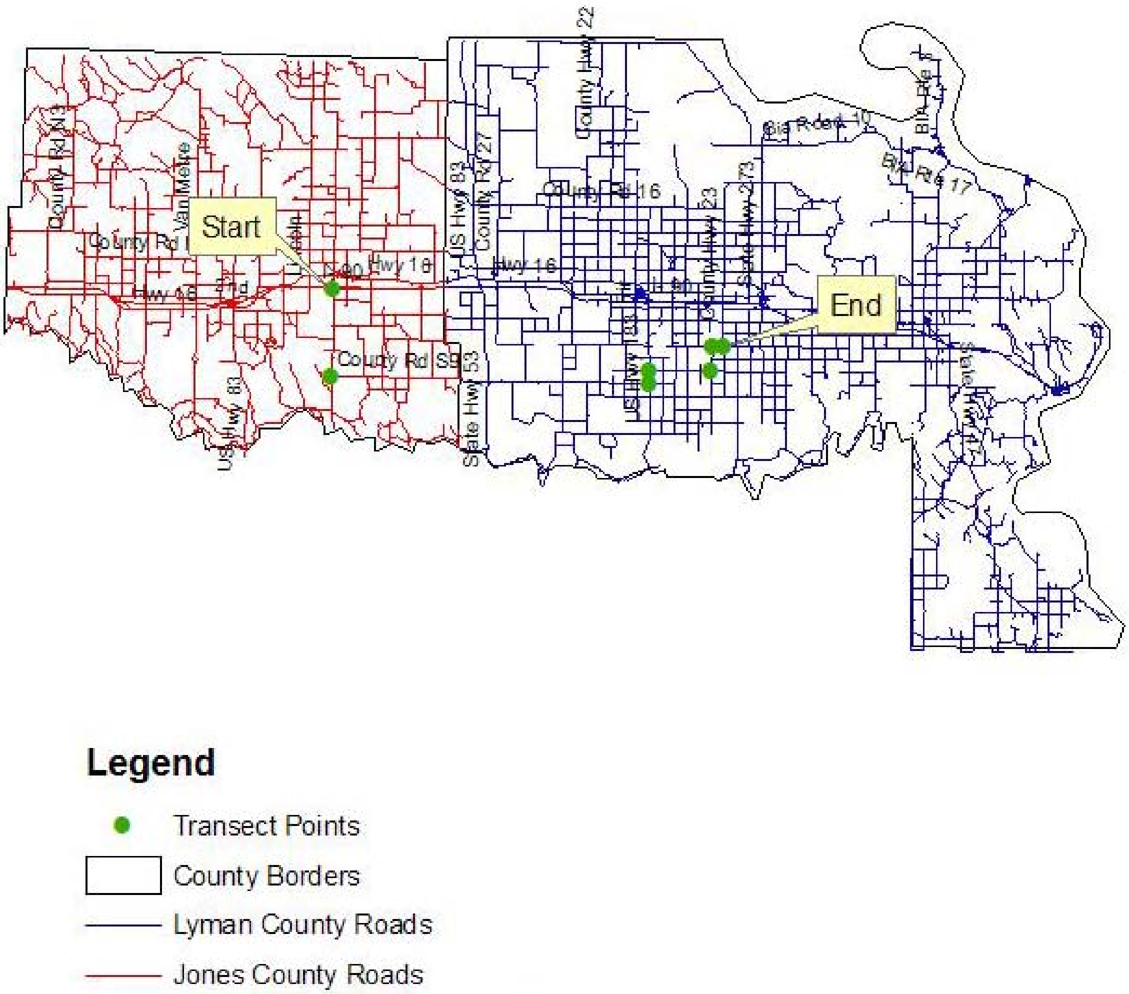
Appendix II con't. Map of the jackrabbit spotlight survey transect in Perkins County in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Jones and Lyman Counties in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	Jones	South	CR-S6	I-90	43.90688333	-100.5470667	7
1	Jones	East	CR-S6	CR-S9	43.80665	-100.54645	25
2	Lyman	North	CR-S9	HIWAY 183	43.80396667	-100.0413333	1
3	Lyman	East		HIWAY 183	43.81845	-100.0412333	5
4	Lyman	North			43.81856667	-99.94206667	2
5	Lyman	East			43.84728333	-99.9421	1
End	Lyman				43.8474	-99.92203333	

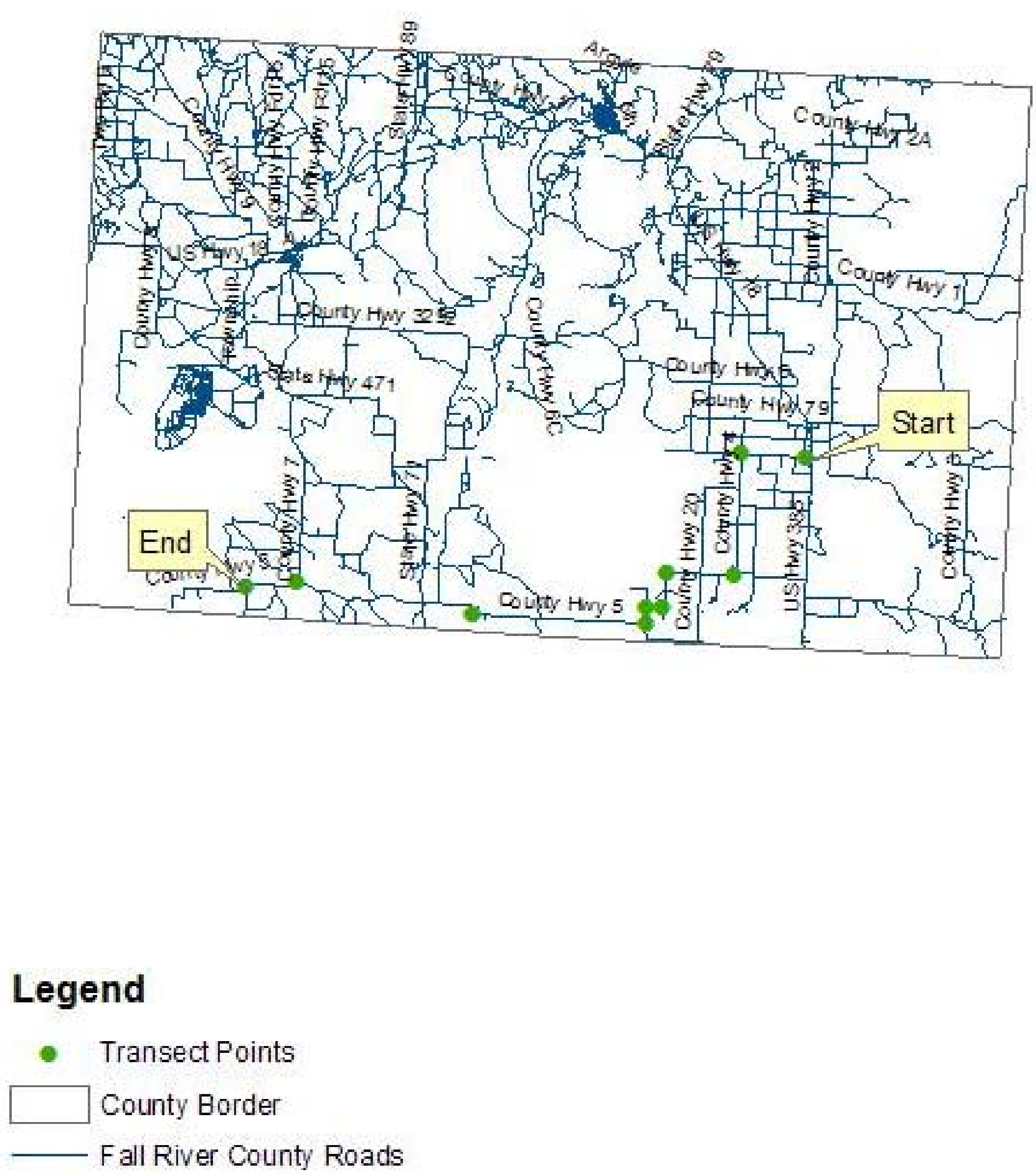
Appendix II con't. Map of the jackrabbit spotlight survey transect in Jones and Lyman Counties in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Fall River County in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	FALL RIVER	West	HIWAY 385	CR-4A	43.1587	-103.2353167	4
1	FALL RIVER	South	CR-4	CR-4A	43.15846667	-103.3078167	7
2	FALL RIVER	West	CR-4	CR-5	43.05898333	-103.3077833	4
3	FALL RIVER	South		CR-5	43.05728333	-103.3859333	2
4	FALL RIVER	West		CR-5C	43.02875	-103.38645	1
5	FALL RIVER	South	CR-5G	CR-5C	43.02836667	-103.4058333	1
6	FALL RIVER	West		CR-5	43.01406667	-103.4060667	10
7	FALL RIVER	West		CR-5	43.01416667	-103.6017	10
8	FALL RIVER	West		CR-6412	43.03318333	-103.7999333	3
End	FALL RIVER		CR-5A	CR-6412	43.02595	-103.8575333	

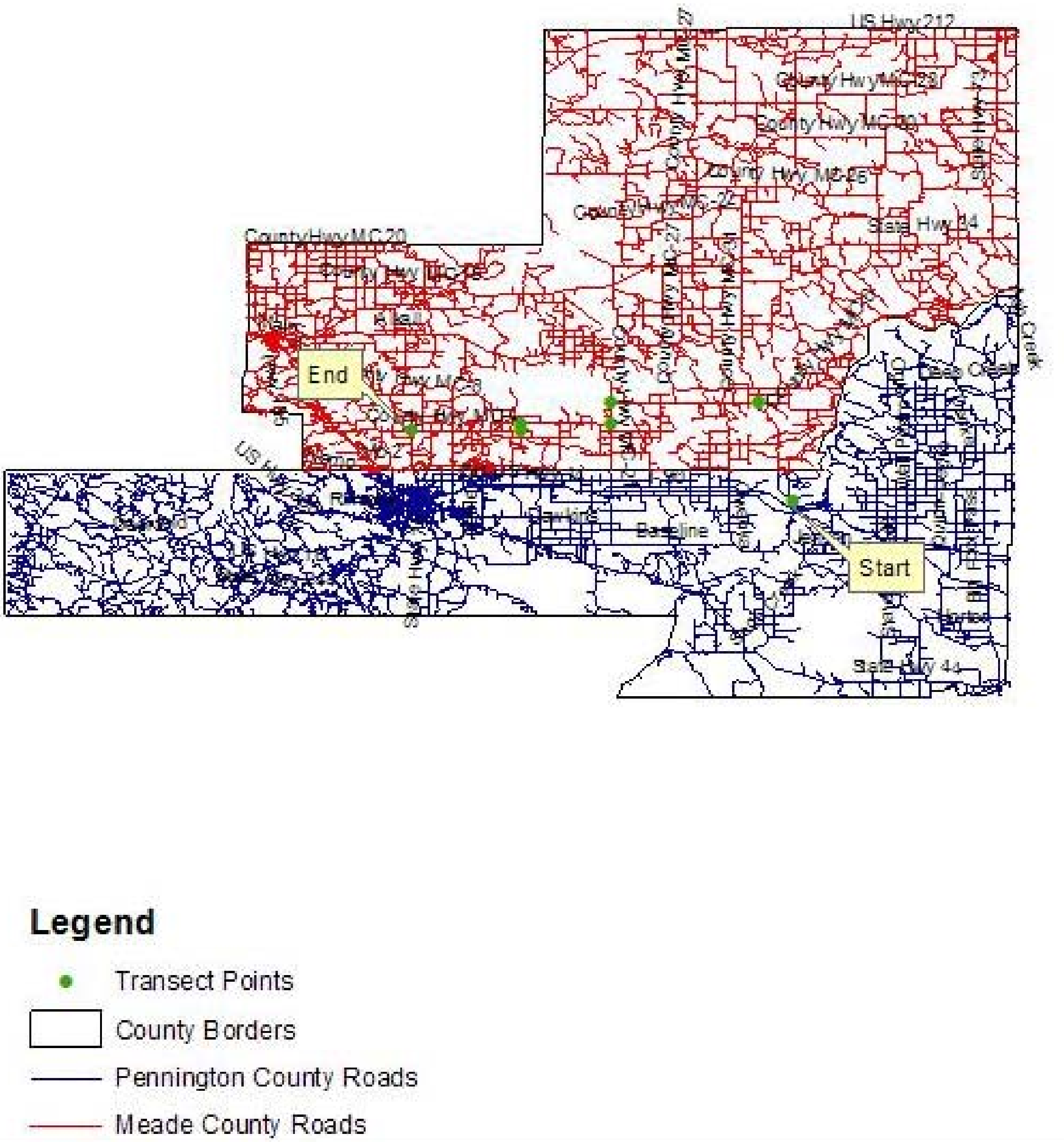
Appendix II con't. Map of the jackrabbit spotlight survey transect in Fall River County in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Meade and Pennington Counties in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	Pennington	North	ELM SPRINGS RD	180 Ave	44.08235	-102.4563833	14.5
1	MEADE	West	ELM SPRINGS RD	215ST	44.28426667	-102.52795	14.8
2	MEADE	South	NEW UNDERWOOD	215ST	44.28223333	-102.8292	2.8
3	MEADE	West	NEW UNDERWOOD	ELK CREEK	44.24093333	-102.8293167	9
4	MEADE	South	152AVE	ELK CREEK	44.24196667	-103.01015	1
5	MEADE	West	152AVE	BEND RD	44.22745	-103.0102667	11
End	MEADE		141AVE	BEND RD	44.22946667	-103.2314667	

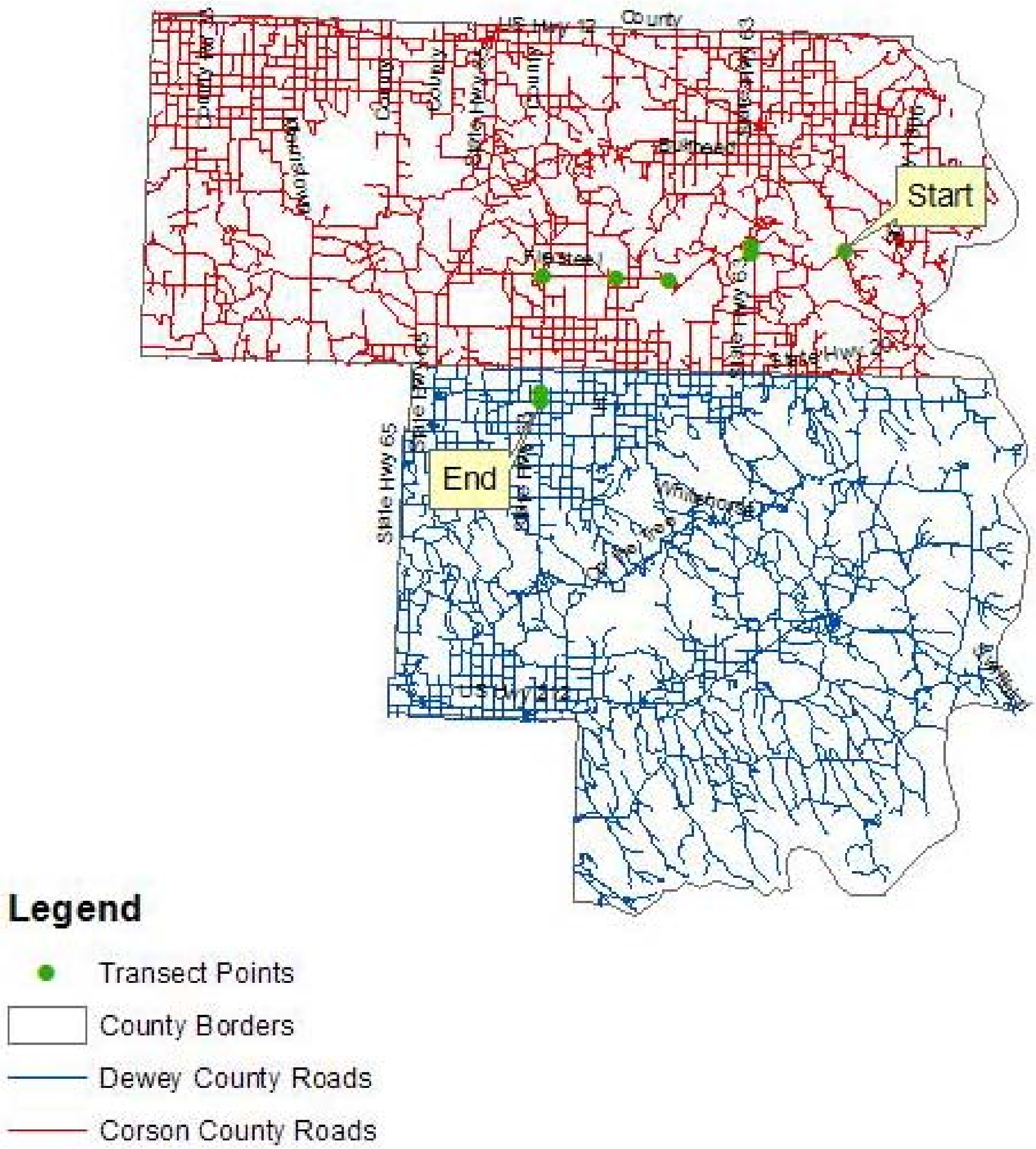
Appendix II con't. Map of the jackrabbit spotlight survey transect in Meade and Pennington Counties in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Corson and Dewey Counties in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	Corson	West	HIWAY 12	BIA 4	45.6463	-100.6371667	9.7
1	Corson	North	HIWAY 63	BIA 4	45.63885	-100.8186	1
2	Corson	West	HIWAY 63	BIA 4	45.65051667	-100.8223667	9.8
3	Corson	West			45.601	-100.9809833	4.8
4	Corson	West			45.60306667	-101.0800167	7
5	Corson	South	Cr-3B	124	45.60301667	-101.2237	12
End	Dewey		HIWAY 63 S	HIWAY 20	45.4293	-101.2236833	

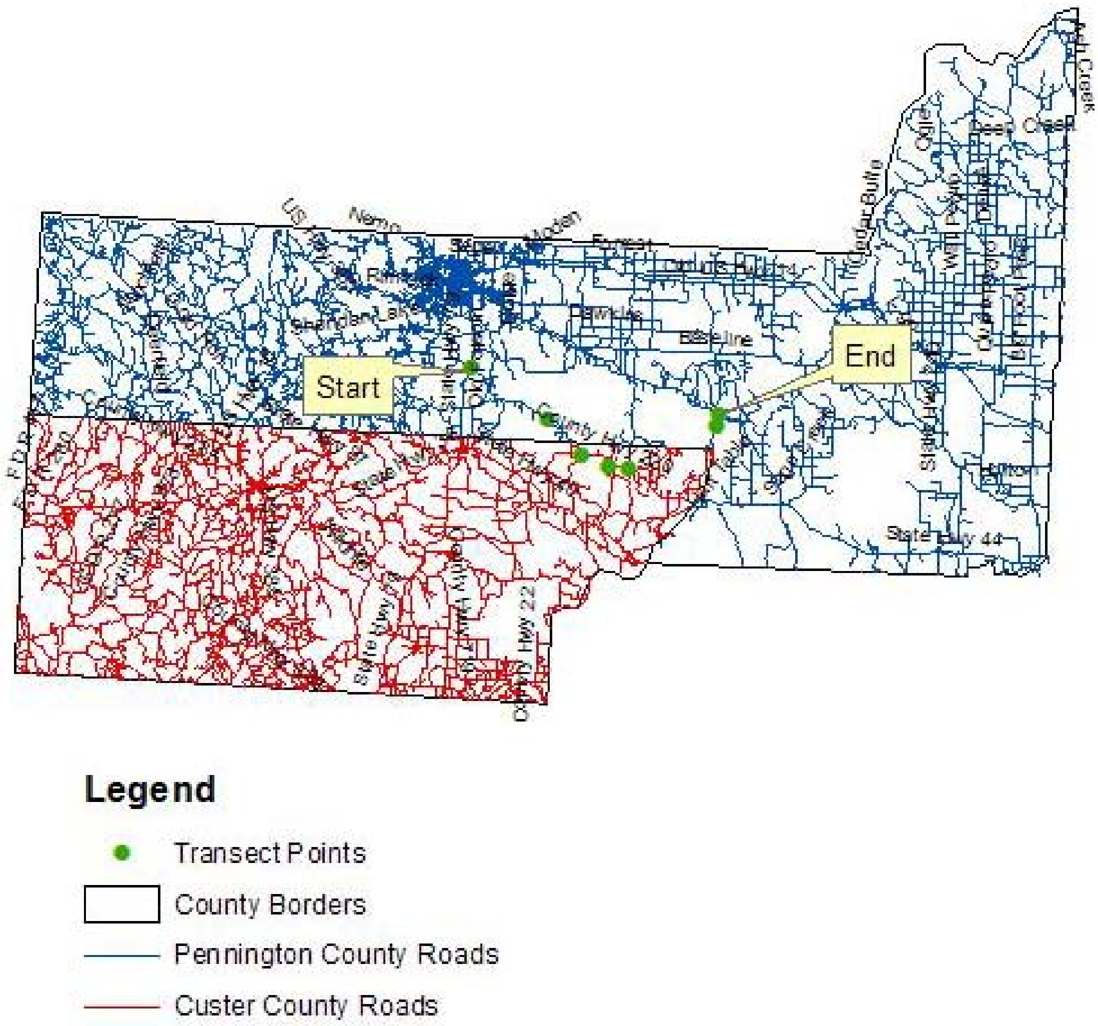
Appendix II con't. Map of the jackrabbit spotlight survey transect in Corson and Dewey Counties in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Pennington and Custer Counties in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	Pennington	Southeast	Hiway 79	L Spring Creek	43.95733333	-103.1854333	10.7
1	Pennington	Southeast		L Spring Creek	43.88916667	-103.0242167	6
2	Custer	East	S Creek Cutoff		43.83998333	-102.9543333	3.5
3	Custer	East			43.82511667	-102.89905	2
4	Custer	Northeast	160th Ave		43.82283333	-102.85945	16.7
5	Custer	North			43.88983333	-102.6893333	1.3
End	Pennington		Creston Rd.	East HWY 44	43.90628333	-102.6830167	

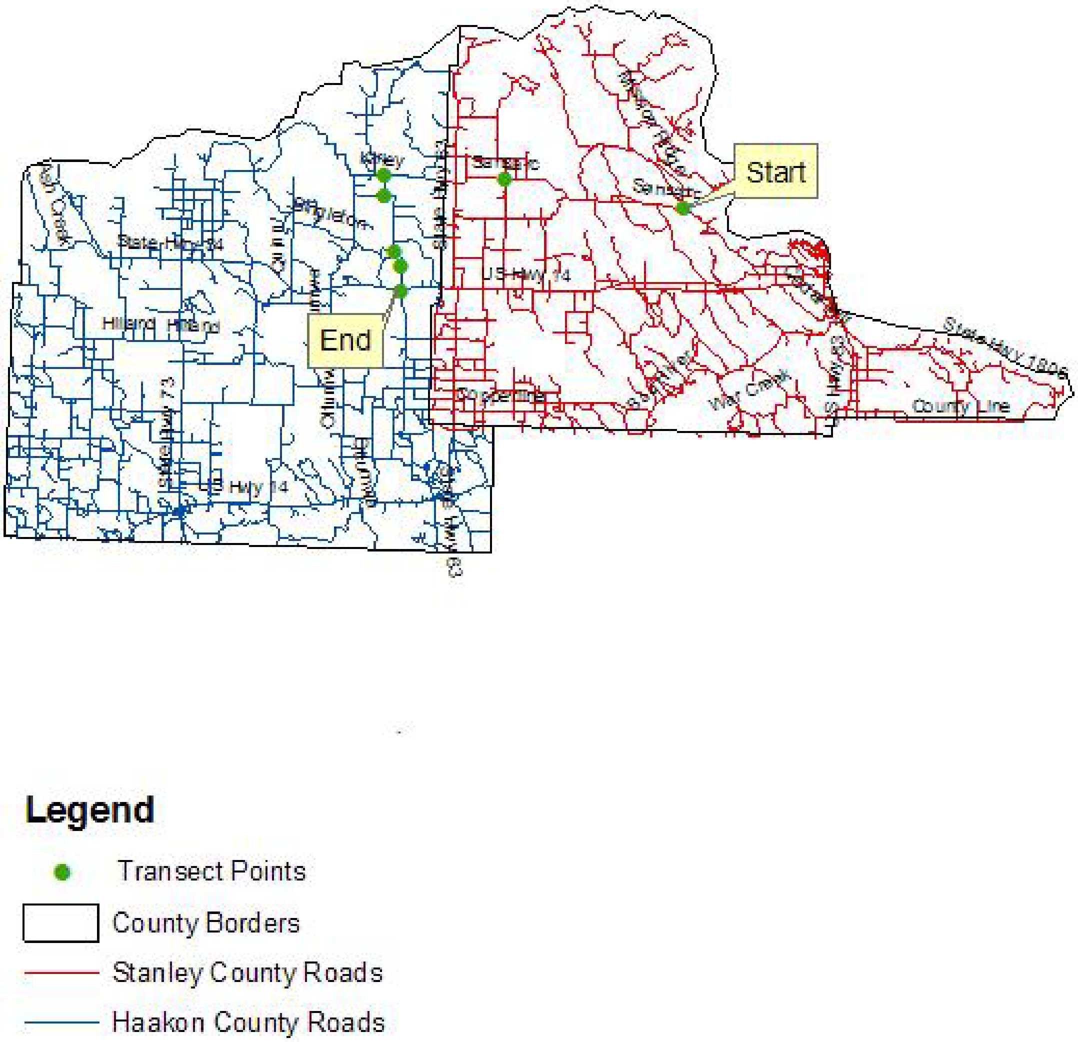
Appendix II con't. Map of the jackrabbit spotlight survey transect in Pennington and Custer Counties in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Stanley and Haakon Counties in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	Stanley	West	Hiway 1806	Sanarc Rd	44.49458333	-100.6784833	17.8
1	Stanley	West	Hayes Rd	Sanarc Rd	44.53128333	-101.0338167	11.8
2	Haakon	South		Kirley Rd	44.5315	-101.2759333	2
3	Haakon	South			44.50288333	-101.2758667	5.7
4	Haakon	South			44.42241667	-101.2527333	1.7
5	Haakon	South			44.40036667	-101.2358833	2.2
End	Haakon			Hiway 34	44.36755	-101.2359	

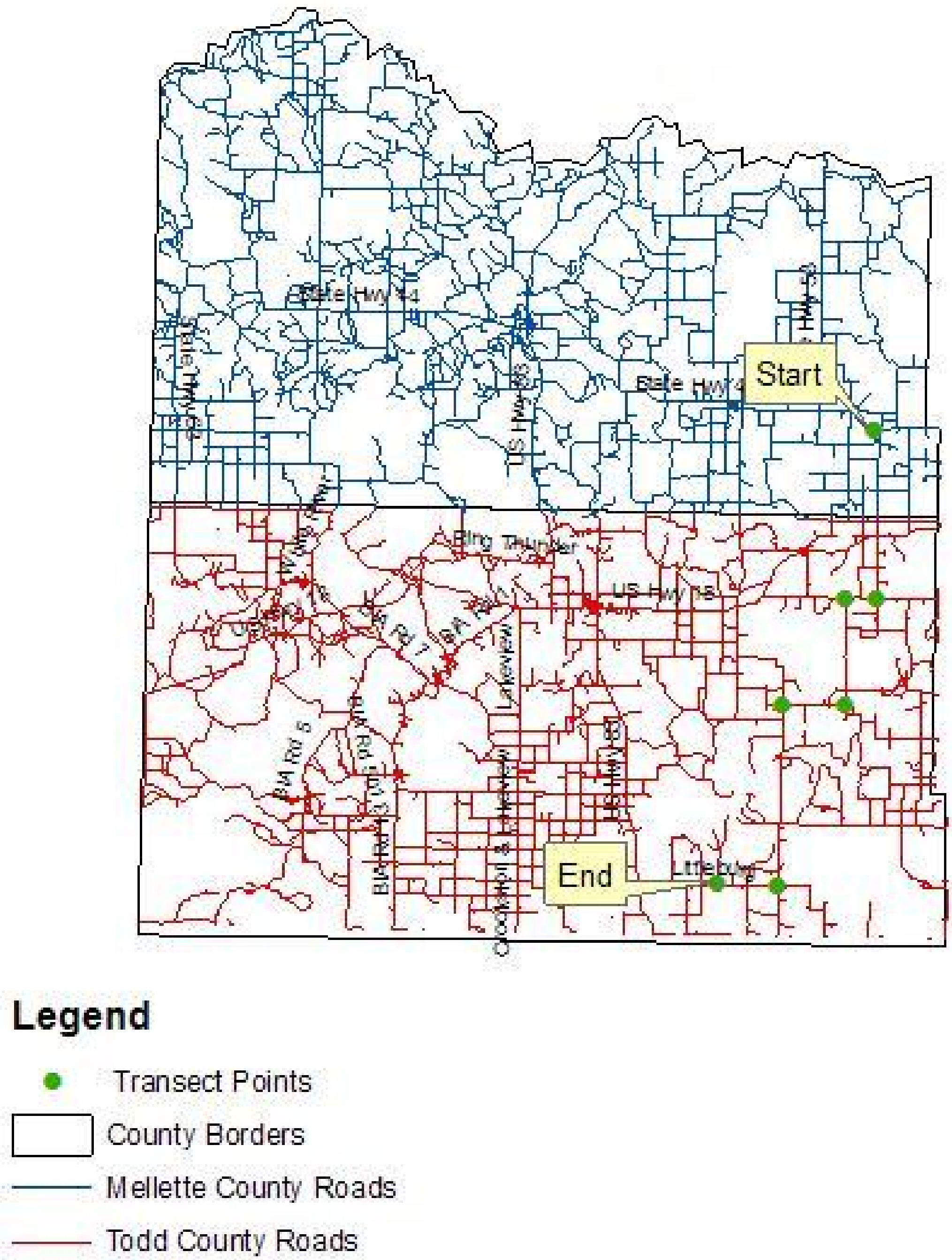
Appendix II con't. Map of the jackrabbit spotlight survey transect in Stanley and Haakon Counties in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Todd and Mellette Counties in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	MELLETTE	South	141	Hiway 44	43.47575	-100.2996667	11
1	TODD	West	141	138	43.31755	-100.2933167	2
2	TODD	South	137	138	43.31748333	-100.3319	7
3	TODD	West	137	135	43.21613333	-100.3325	4
4	TODD	South	136	135	43.21615	-100.4118	12
5	TODD	West	136	Littleburg Rd	43.04586667	-100.4133833	4
End	TODD		118	Littleburg Rd	43.04585	-100.492	

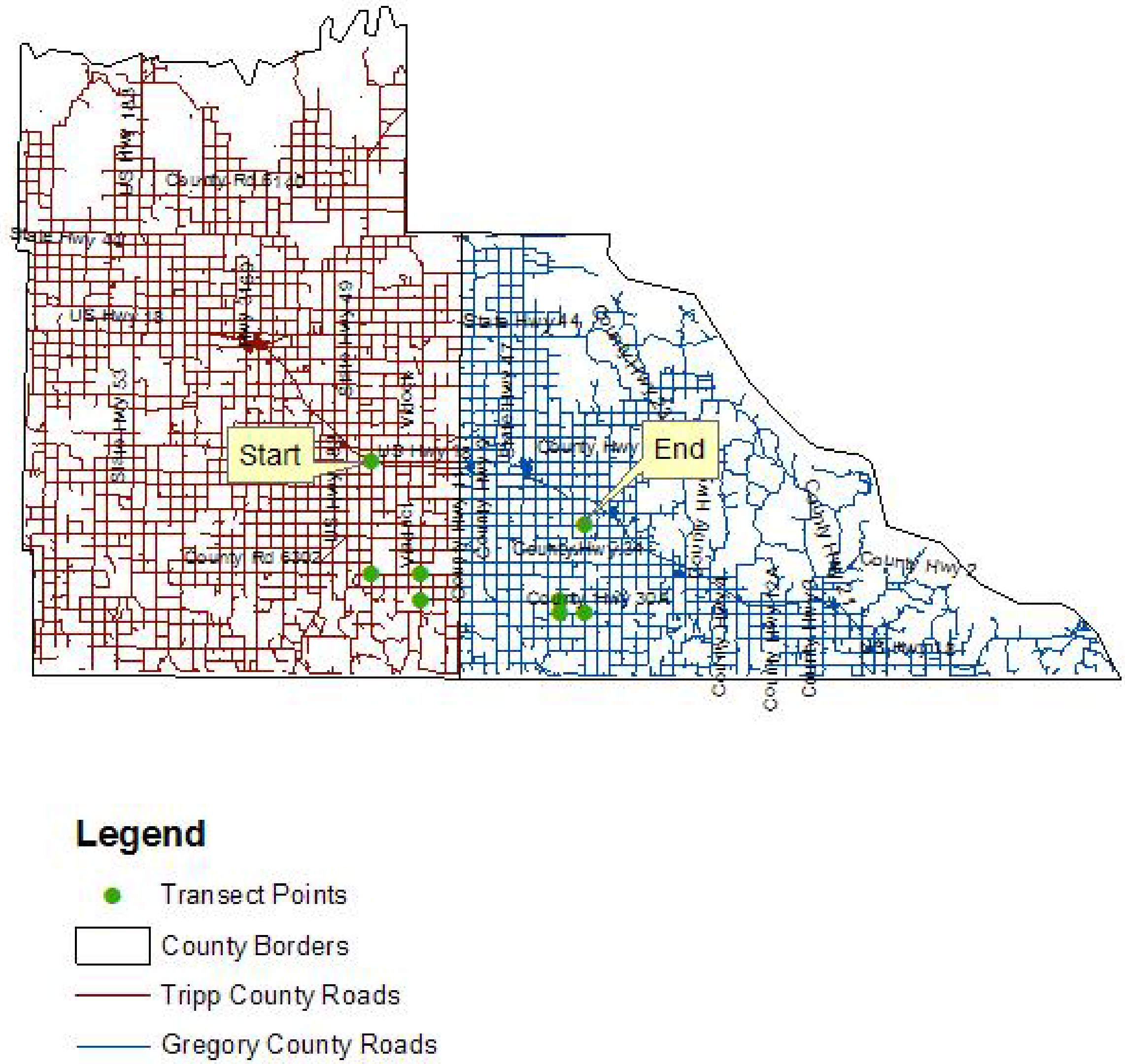
Appendix II con't. Map of the jackrabbit spotlight survey transect in Todd and Mellette Counties in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Tripp and Gregory Counties in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	TRIPP	South	325	287	43.24131667	-99.67243333	9
1	TRIPP	East	325	296	43.11103333	-99.67221667	4
2	TRIPP	South	329	296	43.11106667	-99.59345	2
3	TRIPP	East	329	298	43.08211667	-99.59343333	11
4	GREGORY	South	340 (CR-20)	298 (CR-14)	43.0822	-99.37583333	1
5	GREGORY	East	340 (CR-20)	299 (CR-18)	43.0678	-99.3758	2
6	GREGORY	North	342	299 (CR-18)	43.06776667	-99.33643333	9
End	GREGORY		342	Hiway 18	43.169	-99.33633333	

Appendix II con't. Map of the jackrabbit spotlight survey transect in Tripp and Gregory Counties in western South Dakota.



Appendix II con't. Location of the jackrabbit spotlight survey transect in Shannon and Bennett Counties in western South Dakota.

Point	County	Direction	N/S Road	E/W Road	Latitude	Longitude	Miles to Next Turn
Start	BENNETT	West			43.20145	-101.8116833	5
1	BENNETT	North			43.20161667	-101.91055	1
2	BENNETT	West			43.21596667	-101.9107333	4
3	BENNETT	South			43.21625	-101.99065	2
4	BENNETT	West			43.18726667	-101.99055	7
5	SHANNON	South			43.18725	-102.1290333	4
6	SHANNON	West			43.12928333	-102.1287167	5
7	SHANNON	South			43.12953333	-102.2188833	5
8	SHANNON	West			43.06125	-102.2192333	8
End	SHANNON				43.06103333	-102.3769	

Appendix II con't. Map of the jackrabbit spotlight survey transect in Shannon and Bennett Counties in western South Dakota.