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An Evaluation of Deer and Pronghorn Surveys in South Dakota

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AN EVALUATION OF DEER AND PRONGHORN SURVEYS IN SOUTH DAKOTA

BY

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ESTIMATING POPULATION SIZE OF DEER IN THE BLACK HILLS AND AN EVALUATION OF FALL CLASSIFICATION SURVEYS FOR DEER AND PRONGHORN IN SOUTH DAKOTA

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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ABSTRACT

AN EVALUATION OF DEER AND PRONGHORN SURVEYS IN SOUTH DAKOTA

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To properly manage white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), and the American pronghorn antelope (*Antilocapridae americana*), wildlife managers must identify population perimeters, sample size, age and sex ratios of these three species. The primary objective of this study was to evaluate age and sex ratios and determine a minimum sample size for each study area for all deer species and pronghorn, in addition to deriving a methodology and population estimate for white-tailed deer in the Black Hills.

Sample size needed for both species of deer and pronghorn ranged from 60-70 groups of does. Age ratios calculated from daylight counts did not differ between September and October (P =0.13) for white-tailed deer. Comparison of September and October differed (P $\leq$0.001) indicating that October ($\bar{x}$ =0.85) had a higher age ratio than did September ($\bar{x}$ =0.56) for spotlight counts. Sex ratios calculated from daylight counts differed (P =0.001) between September ($\bar{x}$ =0.17) and October ($\bar{x}$ =0.21) for white-tailed deer. Comparison of months for spotlight counts differed (P =0.02) indicating that October ($\bar{x}$ =0.27) had a higher sex ratio than September. Mule deer age ratios calculated

from daylight counts did not differ (P =0.36) between September ($\bar{x}$ =0.62) and October ($\bar{x}$ =0.66). Mule deer sex ratios calculated from daylight counts did not differ (P =0.05) between September ($\bar{x}$ =0.26) and October ($\bar{x}$ =0.31).

A comparison of August to September for pronghorn was performed at study area level to determine if age ratios differed; high density study areas did differ (P =0.02), whereas medium (P =0.03) and low density (P =0.20) study areas did not differ. We also did a similar comparison for sex ratios of pronghorn and found all study areas were similar (P =0.05) between years.

For Black Hills, white-tailed deer, we utilized 42 transects in 2012, 2013 and 2014. In 2014 we also added 20 additional transects to increase our sample size. We estimated 54,156 white-tailed deer (95% CI =36,864-71,451) in 2012, 37,567 white-tailed deer (95 % CI =27,251-47,913) in 2013, 43,899 white-tailed deer (95% CI =31,316-56,491) in 2014 and 41,886 white-tailed deer (95% CI =31,352-52,423) in 2014 with 20 additional transects.

This data can be used to improve population models and survey methodologies for both deer species and pronghorn in South Dakota and provide an index to white-tailed deer populations for the Black Hills of South Dakota. When quantifying age and sex ratios of deer, habitat types need to be given consideration. When quantifying age ratios of pronghorn, consideration should be given to other factors such as behavior of pronghorn and morphometric differences. When deriving a population estimate for deer in the Black Hills wide confidence intervals were obtained. Therefore, using the estimate as an index over several years is recommended.

CHAPTER 1

GENERAL INTRODUCTION AND STUDY SITE DESCRIPTION

General Introduction

Knowledge of deer and pronghorn population dynamics is important for proper wildlife management. White-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), and pronghorn (*Antilocapridae americana*) are of interest economically, biologically, and aesthetically. White-tailed deer are among the most sought after big game species in North America (McCullough 1987); mule deer and pronghorn are also highly desired by hunters. It was estimated in 2011 that hunting expenditures totaled $597 million, in the U.S. with approximately 270,000 resident hunters taking part in South Dakota's various hunting seasons; furthermore, 384,000 non-consumptive users took part in wildlife watching in 2011 (United States Fish and Wildlife Service 2011). Given a wide constituency, deer and pronghorn herds need to be properly managed to adequately meet the needs of stakeholders. Personal opinion and theory alone cannot be used to accurately manage wildlife populations (McCullough 1987).

White-tailed deer and pronghorn were nearly extirpated due to human encroachment, overharvest, and intense farming practices by the late 1800's (Nelson 1925, Cook 1945,). During the early to mid- 1900's, populations of deer and pronghorn began to rebound due to newly implemented conservation practices, regulated hunted, and land use management practices (Cook 1945, Yokum et. al. 1996). South Dakota Game, Fish and Parks (SDGFP) estimated the population of white-tailed deer at 375,000 (CI=286,000-464,000) and mule deer at 110,000 (CI=77,000-143,000) statewide in 2015 not including the black hills (SDGFP 2016). Black Hills estimates for white-tailed deer were 51,000 (CI=36,000-65,000) and mule deer were 6,500 (CI=4,500-8,500, SDGFP 2016). A high public demand for both deer species exists total licenses sold in 2015 amounted to 99,336 which represented a total of 111,050 tags (SDGFP 2016). Demand for pronghorn also exists in the state. Their population were estimated at 26,000 (CI=18,000-33,000) with 3,486 firearms tags issued in 2015 (SDGFP 2016).

All three species utilize different niches and mule deer and pronghorn thrive on different landscapes, yet management practices and sampling techniques for each species can be similar (Rabe 2002). Currently, SDGFP uses several variables in their population models such as: annual adult survival rates, annual fawn survival rates, pregnancy rates, harvest, sex and age ratios. Primary data used for modeling is gathered from survival data, hunter harvest data and observations through herd composition surveys (Robling 2011, SDGFP 2016).

The primary objectives of this study were to: 1) Estimate population size of deer in the Black Hills, and; 2) Evaluate herd composition surveys for deer and pronghorn in South Dakota. Secondary objectives for the Black Hills region were: 1) Compare estimates of population size of deer among management units; 2) Evaluate factors affecting population size of deer relative to management units in the Black Hills and; 3) Develop population model and survey methodology and recommendations for implementation of survey procedures in the Black Hills. Secondary objectives for evaluation of herd composition surveys for deer and pronghorn were to: 1) Determine minimum sample size for sampling deer and pronghorn herds; 2) Compare population estimates generated from data collected in September and October for deer and August and September for pronghorn; 3) Compare spotlight and daylight counts for deer; 4)

Assess feasibility of obtaining male:female ratios from deer survey data, and; 5) Evaluate impacts of other survey variations such as: a) counting all deer observed vs. only conclusive counts; b) effect of distance from cover on population estimates; and c) Compare estimates derived using one observer for daylight and two observers during spotlight for deer.

Study Area

Black Hills Study Area

Survey periods were from 15 August to 30 August 2012 and 2013, and these periods were chosen to alleviate scheduling conflicts with deer and pronghorn herd composition surveys. The Black Hills (Figures 1 and 2) is an isolated, mountainous region in western South Dakota, which is approximately 190 km north to south and 95 km east to west (Petersen 1984). Total area of the Black Hills is approximately 8,400 km^2 with elevation ranging from 973-2,202 m above mean sea level (Orr 1959, Turner 1974, Fecske et al. 2002). Our study area covered 5,572.6 km^2 and included all areas within the Black Hills Fire Protection District (USDA 1997), which falls within portions of Lawrence, Pennington, Custer, and Fall River counties. Primary land uses include timber production and livestock grazing. Public lands in the study area are approximately 4,167 km^2 of the region and were primarily managed by the United States Forest Service (USFS) and Bureau of Land Management (BLM). The study area contained sub-units that are described by South Dakota Game Fish and Parks (SDGFP) which correspond to Black hills deer hunting units (Figure 2.) The area of each subunit is as follows: unit 1, 799.93 km^2; unit 2, 2,280.79 km^2; unit 3, 1,000.67 km^2; and unit 4, 1,497.14 km^2.

Mean annual temperature ranges from 5º C to 9º C with extremes of -40º to 44º C (Orr 1959). Mean annual precipitation is > 66 cm (Orr 1959) with snowfall exceeding 254 cm at upper elevations (Thilenius 1972). Dominant over story consisted of ponderosa pine (*Pinus ponderosa*) with interspersed stands of quaking aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*). Although not as common, white spruce (*Picea glauca*), mountain mahogany (*Cercocarpus montanus*), and mountain juniper (*Juniperus scopulorum*) were present (McIntosh 1949, Thilenius 1972, Richardson and Petersen 1974, Severson and Thilenius 1976, Hoffman and Alexander 1987). Primary understory vegetation consisted of various forbs, grasses, and shrubs, including big bluestem (*Andropogon gerardii*), buffalo grass (*Buchloe dactyloides*), snowberry (*Symphoricarpos albus*), serviceberry (*Amelanchier alnifolia*), woods rose (*Rosa woodsii*), juniper (*Juniperus communis*), cherry (*Prunus spp.*), Oregon grape (*Berberis repens*), and bearberry (*Arctostaphylos uva-ursi*; Thilenius 1972, Severson and Thilenius 1976).

Herd Composition Study Area

Deer Study Area

The deer herd composition study area contained six study areas that were distributed throughout South Dakota and covered several ecoregions and land use types. Each study area had multiple deer hunting units described by South Dakota Game Fish and Parks (South Dakota Department of Game Fish and Parks 2015) and were analyzed based upon individual study areas.

Study area 1 (Figures 1 and 2) was the Black Hills of South Dakota, and shared the same boundaries as the Black Hills deer study area.

Study area 2 (Figure 3) included portions of Meade (Unit 49a), Custer (21a), and Pennington (Unit 02a) counties and was approximately 8,780 km^2. Mean (30-yr) monthly temperature ranged from -14.6º C to 23.5º C with mean (30-yr) annual rainfall of 42.3 cm (South Dakota Office of Climatology 2014). The sampling block was located in the Northwestern Great Plains ecoregion and was classified as semiarid Pierre Shale Plains. Terrain was rolling plains with soils of shale, siltstone, and sandstone; features were intermittent buttes and badlands (Bryce et al. 1998). Land use consisted primarily of cattle grazing with occasional corn (*Zea mays*) and wheat (*Triticum aestivum*) production (Bryce et al. 1998, U.S. Department of Agriculture). Land ownership was dominated by private land, however, a mixture of Federal Grasslands, Bureau of Land Management (BLM), State Game Production Areas, State Walk in Areas, and State School and Public lands was present in the study boundary (South Dakota Game, Fish and Parks 2014*b*), equaling 779 km^2.

Dominant vegetation within the sampling block was mostly native rangeland that included western wheatgrass (*Agropyron smithii)*, thick spike wheatgrass (*Agropyron dasystachyum*), needleandthread (*Stipa comata*), green needlegrass (*Stipa viridula*), bluebunch wheatgrass (*Psuedoroegneria spicata*), blue gamma (*Bouteloua gracilis*), and thread leaf sedge (*Carex lanuginosa*) (Johnson and Larson 1999). Many shrubs and forbs also were found throughout the area, including leadplant (*Amorpha canescens*), prickly pear (*Opuntia spp*.), fringed sagewart (*Artemisia frigida*), purple coneflower (*Echinacea angustifolia*), prairie cone flower (*Ratibida columnifera*), dotted gay feather (*Liatris puncata*), Missouri goldenrod (*Solidago missouriensis*), and western snowberry (*Symphoricarpos occidentalis*, Johnson and Larson 1999).

Study area 3 (Figure 3) was located in the central part of South Dakota and included portions of Mellette (Unit 50a), Lyman (Unit 45a), Jones (Unit 41a), and Tripp (Unit 60a) counties equaling 5,971 km^2. Mean (30-yr) monthly temperature ranged from -15.6º C to 27.0º C with mean (30-yr) annual rainfall of 50.2 cm (South Dakota Office of Climatology 2014). The sampling block was located in the Northwestern Great Plains ecoregion and was classified as Sub humid Pierre Shale Plains. Terrain was rolling plains of shale, siltstone and sandstone with intermittent buttes and badland features (Bryce et al. 1998). Land use consisted primarily of cattle grazing with occasional corn and wheat production (Bryce et al. 1998, U.S. Department of Agriculture). Land ownership was dominated by private land; however, State Walk in Areas and State School and Public lands were present in the study boundary (South Dakota Game, Fish and Parks 2014*b*) equaling 101 km^2.

Dominant vegetation was mostly native rangeland that included western wheatgrass, thick spike wheatgrass, needleandthread, green needlegrass, bluebunch wheatgrass, blue gramma, and thread leaf sedge (Johnson and Larson 1999). Shrubs and forbs also were found throughout the study area, including leadplant, prickly pear, fringed sagewart, purple coneflower, prairie cone flower, dotted gay feather, Missouri goldenrod, and western snowberry (Johnson and Larson 1999).

Study area 4 (Figure 4) was also located centrally and included portions of Hughes, Sully, and Potter counties; the area was approximately 5,793 km^2. Mean (30-yr) monthly temperature ranged from -16.4º C to 27.9º C with mean (30-yr) annual rain fall of 50.5 cm (South Dakota Office of Climatology 2014). The sampling block was located in the Northwestern Glaciated Plains ecoregion and was classified as the Southern

Missouri Coteau Slope. Terrain was level to rolling uplands and consisted primarily of mesic soils (Bryce et al. 1998). Land use was dominated by cattle grazing and crop production. Corn, wheat, sunflower (*Helianthus annus*) and soy beans (*Glycine max*) were primary crops in this area (Bryce et al. 1998, U.S. Department of Agriculture). Land ownership was dominated by private land; however, a mixture of Federal Grasslands, State Game Production Areas, State Walk in Areas, and State School and Public lands were present in the study boundary (South Dakota Game, Fish and Parks 2014*b*) equaling 387 km^2.

Dominate Vegetation was mostly native rangeland that included western wheatgrass, thick spike wheatgrass, needleandthread, green needlegrass, bluebunch wheatgrass, blue gramma, and thread leaf sedge (Johnson and Larson 1999). Shrubs and forbs also were found throughout the study area, including common cattail (*Typha latifolia*), leadplant, prickly pear, fringed sagewart, purple coneflower, prairie cone flower, dotted gay feather, Missouri goldenrod, and western snowberry (Johnson and Larson 1999).

Study area 5 (Figure 4) was located in Brookings (Unit 06a), Lake (Unit 43a), Moody (Unit 52a), and Minnehaha (Unit 01a) counties; total area was approximately 7,029 km^2. Mean (30-yr) monthly temperature ranged from -18.7º C to 24.6º C with mean (30-yr) annual rainfall of 57.93 cm (South Dakota Office of Climatology 2014). The sampling block was located within two ecoregions; the Prairie Coteau and Loess Prairie regions. Terrain was gently rolling with interspersed seasonal wetlands in the Prairie Coteau region. The Loess region were characterized by rolling glacial till plains with rich fertile soils (Bryce et al. 1998). Land use consisted of cattle ranching and intensive crop production of corn and soybeans on both regions (Bryce et al. 1998, U.S. Department of Agriculture). Land ownership was dominated by private land; however, a mixture of State Game Production Areas and Waterfowl production areas were present in the study boundary (South Dakota Game, Fish and Parks 2014*b*) equating to approximately 133 km².

Native rangeland included western wheatgrass, Big bluestem, little bluestem (*Schizachyrium scoparium*), and porcupine grass (*Stipa spartea*). Other common vegetation included Missouri goldenrod, soft goldenrod (*Solidago mollis*), needleandthread, green needlegrass, side oats gramma (*Bouteloua curtipendula*), blue gramma, and fringed sagewart, and purple cone flower. Wetland areas generally contained prairie cordgrass (*Spartina pectinata*), common reed (*Phragmites australis*), smooth brome (*Bromus inermis*), common cattail (*Typha latifolia*), and reed canarygrass (*Phalaris arundinacea*, Johnson and Larson 1999).

Study area 6 (Figure 4) was located in Day (Unit 22), Clark (Unit 18), and Codington (Unit 05) counties and was approximately 7,182 km^2 in size. Mean (30-yr) monthly temperature ranged from -19.6º C to 24.1º C with mean (30-yr) annual rain fall of 55.7 cm (South Dakota Office of Climatology 2014). This sampling block was located on the Prairie Coteau and terrain was gently rolling with interspersed seasonal wetlands (Bryce et al. 1998). Land use consisted of cattle ranching and intensive crop production of corn, wheat, and soybeans (Bryce et al. 1998, U.S. Department of Agriculture). Land ownership was dominated by private land; however, a mixture of State Game Production Areas and Waterfowl production areas were present in the study boundary (South Dakota Game, Fish and Parks 2014*b*) equaling 239 km².

Native rangeland included western wheatgrass, big bluestem, little bluestem, and porcupine grass. Other common vegetation included Missouri goldenrod, soft goldenrod, needleandthread, green needlegrass, side oats gramma, blue gramma, fringed sagewart, and purple cone flower. Wetland areas generally contained prairie cordgrass, common reed, smooth brome, common cattail (*Typha latifolia*), and reed canary grass (Johnson and Larson 1999).

Pronghorn Study Area

The pronghorn herd composition study area contained three study sites distributed throughout western South Dakota (Figure 5). Unlike the deer study, those for pronghorn were not adjacent units but were areas identified by South Dakota Game, Fish and Parks (SDGFP) derived from 2011 spring aerial surveys, and classified as high, medium, and low population density areas.

Study area 1, high density, included portions of Butte (Unit 15b) and Fall River (Unit 27A) counties. The study area was approximately 10,414 km^2. Mean (30-yr) monthly temperature ranged from -13.2º C to 24.6º C with mean (30-yr) annual rainfall of 44.88 cm for Fall River County (South Dakota Office of Climatology 2014). Butte County ranged from -14.7º C to 25.2º C with mean (30-yr) annual rainfall of 45.2 cm (South Dakota Office of Climatology 2014).

Study area 2, medium density, included portions of Haakon (Unit 31a) and Meade (Unit 49b) counties. The study area was approximately 9,152 km^2. Mean (30-yr) monthly temperature ranged from -15.7º C to 27.0º C with mean (30-yr) annual rainfall of 44.1 cm for Haakon County (South Dakota Office of Climatology 2014). Meade county ranged from –15.2º C to 26.9º C with mean (30-yr) annual rainfall of 46.2 cm (South Dakota Office of Climatology 2014).

Study area 3, low density, included portions of Dewey (Unit 24a) and Mellete (Unit 50a) counties. The study area was approximately 9,723 km^2. Mean (30-yr) monthly temperature ranged from -15.7º C to 27.0º C with mean (30-yr) annual rainfall of 44.1 cm for Dewey County (South Dakota Office of Climatology 2014). Mean (30-yr) monthly temperature for Mellette County ranged from –15.7º C to 26.9º C with mean (30-yr) annual rainfall of 46.2 cm (South Dakota Office of Climatology 2014).

All three blocks were located in the Northwestern Great Plains ecoregion and were classified as semiarid Pierre Shale Plains. Terrain was rolling plains characterized by sagebrush steppe with soils of shale, siltstone, and sandstone; features were intermittent buttes and badlands (Bryce et al. 1998). Land use was grazing with occasional corn and wheat production (Bryce et al. 1998, U.S. Department of Agriculture). Land ownership was dominated by private land; however, a mixture of Federal Grasslands, BLM, State Game Production Areas, State Walk in Areas, and State School and Public lands were present in the study boundary (South Dakota Game, Fish and Parks 2014*b*) equaling 2816 km^2.

Dominate vegetation was mostly native rangeland that included western wheatgrass, thick spike wheatgrass, needleandthread, green needlegrass, bluebunch wheatgrass, blue gamma, and thread leaf sedge (Johnson and Larson 1999). Many shrubs and forbs also were found throughout the area, including leadplant, prickly pear, fringed sagewart, purple coneflower, prairie cone flower, dotted gay feather, Missouri goldenrod, and western snowberry (Johnson and Larson 1999).

CHAPTER 2

ESTIMATING POPULATION SIZE OF DEER IN THE BLACK HILLS

Introduction

White-tailed deer (*Odocoileus virginianus*) are important to the Black Hills not only ecologically but also economically. In 2011, consumptive users spent an average of $1,457 annually on big game hunting and non-consumptive users spent an average of $981 per year nationwide (U.S. Fish and Wildlife Service 2014). More recently, there were 3,741 licenses sold to hunters for the 2015 Black Hills firearm deer season with 2,840 white-tailed deer harvested and 76 mule deer harvested (South Dakota Department of Game Fish and Parks [SDGFP] 2015).

White-tailed deer numbers in North America were estimated to be 300,000 in the late 19th century and 500,000 in the early 20th century (Downing 1987). The Black Hills of South Dakota, United States, have historically been occupied by white-tailed deer (Ludlow 1875) and mule deer (*Odocoileus hemionus*). As European settlers colonized the Black Hills, deer were nearly extirpated due to unrestricted market hunting (Bever 1957, Richardson and Peterson 1974). This did not go unnoticed and the Dakota Territory government enforced the first season in 1883 and prohibited deer hunting from January 1 until September 1 (Bever 1957). The Lacey Act and the limited number of deer in the early 1900's helped to eliminate market hunting in South Dakota (McCabe 1984) but, it was not until the implementation of the buck laws of 1911 and 1921 that ultimately lead to a marked increase in South Dakota's deer herd (Bever 1957, Richardson and Petersen 1974).

Prior to the 1950's in the Black Hills of South Dakota, deer abundance was estimated primarily by harvest and landowner surveys (SDGFP 1950). In 1953, pellet counts were implemented and a total deer population was derived (N=107,771) from these surveys for the Black Hills (Bever 1954). These surveys were continued until the 1980’s. Spotlight studies had also been conducted in the Black Hills (SDGFP 1950, Progulske and Duerre 1964, SDGFP 1974) and were used to determine herd composition ratios from 1970 to 1980 by SDGFP. In the early 1980’s, the surveys were discontinued due to a lack of funding, staffing, and data reliability issues (D. Mann and R. Hauck, SDGFP, Rapid City, SD, Pers. Com.). SDGFP currently uses several inputs to estimate deer populations including: annual adult survival rates, annual fawn survival rates, sex ratios, and recruitment rates. Other data used for modeling is collected from hunter harvest surveys, research, and observations during herd composition surveys (Robling 2011, SDGFP 2015). In 2015, the population was estimated to be 51,000 (95% CI: 36,000-65,000) white-tailed deer and 6,500 (95% CI: 4,500-8,500) mule deer in the Black Hills (SDGFP 2016).

In an effort to reevaluate spotlight survey methodology and to possibly reestablish spotlight surveys in the Black Hills we utilized general randomized tessellation stratified (GRTS) sampling (Stevens and Olsen 1999; Stevens and Olsen 2003; Stevens and Olsen 2004) and Distance Sampling (Program Distance) (Buckland et. al. 2001), to conduct spotlight surveys in the Black Hills in an effort to improve data collection and analyses for estimating population size of white-tailed deer. The objectives of this study were to 1) estimate population size of white-tailed deer in the Black Hills using GRTS sampling, 2) compare estimates of population size of white-tailed deer among management units within the Black Hills, 3) evaluate factors affecting population size of white-tailed deer relative to management units, 4) develop a population model and survey methodology, and 5) provide recommendations to SDGFP for implementation of the survey methodology in the Black Hills.

Methods

Pilot Study Methods

To address potential logistical problems related to data collection, we conducted a pilot project from 18-21 October 2011 to determine final survey protocol. Goals of the pilot project were to determine: 1) if the number of deer observed in spotlight surveys differed when using one or two observers; 2) how time of day affected the sightability rate along transects; 3) determine the length of transects that provided minimum observations for generating accurate estimates; 4) generate an estimate of time required to sample transects, and; 5) use the data collected during the pilot study to design survey methods that were effective, efficient, and logistically reasonable. Five transects were surveyed on the east side of the Black Hills located within 45 minutes of Rapid City, South Dakota. Transects selected were greater than 8 km in length and ranged in length from 9.7 to 17 km. Two track Roads (Type A and B; Bureau of Land Management 2006. Tech. Note 422, Washington D.C.) were selected as transects because these roads have minimal vehicle traffic within the Black Hills system. Each transect (road) was driven a total of six times: three times with one observer and three times with two observers. Surveys were conducted during three periods of the day: morning, evening, and night. Morning surveys began 0.5 hours before sunrise and ended no later than 1 hour after sunrise. Evening surveys began 1 hour before sunset and ended no later than 0.5 hours after sunset. Night surveys began 30 minutes after sunset and continued until transects were completed. Night surveys were conducted using 4-million-candlepower spotlights (Cyclops Solutions Grand Prairie TX, USA) to locate deer. Each sampling period was surveyed once with one observer and once with two observers. Observers searched both sides of the road during all surveys. When a deer or a group of deer was observed, an initial distance (from observer to deer) was estimated using a rangefinder (Nikon Riflehunter 550, Nikon, Shanghai, China). At that time, a GPS point was downloaded in the Universal Transverse Mercator (UTM) coordinate system (North American Datum NAD 83). The observer would then proceed to a position on the road perpendicular to the deer. From this position, a second estimate of distance to the deer and GPS point were obtained. Deer groups were defined as >1 individual and deer were within 50m of one another.

When deer were observed in a group, distance measurements were estimated from the geographic center of the group. Age class data (buck, doe, fawn, unknown) was also collected, using binoculars or a spotting scope, for all deer observed. We used a two-tailed paired-sample t-test to compare mean deer observed between sampling times and between number of observers (Zar 1999). For our pilot study analyses, each deer was considered an individual unit whether or not it was located in a group (Collier et al. 2007). We set the maximum distance of sightability to 300m. We identified 457 total deer; 188 with one observer and 267 with two observers. Surveys were separated into $Dawn_1$ (dawn survey with one observer) and $Dawn_2$ (dawn survey with two observers) for morning surveys; $Dusk_1$ (one observer) and $Dusk_2$ (two observers) for evening surveys, and $Spot_1$ (spotlight survey with one observer) and $Spot_2$ (spotlight survey with two observers). Total deer observed was calculated for each survey type (Table 1).

The 5 transects, Newton Fork (9.8 km), Bogus Jim (11.9 km), Victoria Creek (17.1 km) Custer Crossing (10.2 km), and Kelly Spur (11.0 km), resulted in a total length of 59.85 km sampled. To estimate total area surveyed we doubled the maximum distance from the transect (0.6 km) that deer were counted and multiplied that by the total length of the transects; total area surveyed was 35.9 km^2. We used this area surveyed to generate a raw, approximate estimate of density. With one observer, estimated density was 5.3 deer/km^2 whereas density with two observers was 7.4 deer/km^2. We tracked age class data for each sampling time and noted that females comprised the majority of deer observed during each survey period; 1 male was observed for every 4.5 females (Figure 6). We evaluated perpendicular distance data between sampling times and noted that most deer were observed within 80 m of the transect (road) (Figure 7).

Study Methods

Our pilot study indicated that night spotlight surveys were more affective than daylight surveys; therefore, we used spotlight surveys for our study. Our methodology for spotlight surveys only changed from the main study in that we collected one distance measure (observer to deer or deer group); we ranged deer at 90-degree angles. General Randomized Tessellation Stratified (GRTS) Sampling (Stevens and Olson 1999, Stevens and Olsen 2003, Stevens and Olsen 2004) was used to determine independent transect points within the Black Hills using ArcGIS 10.2 (ESRI 2012). Initially, 50 sites were selected in the GRTS sample. The random tessellation used a base layer of the entire Black Hills as well as a base map layer from the United States Forest Service (USFS) (USDA Forest Service 2014), which outlined all roads and trails in the Black Hills. Once the random tessellation sampling was completed, each point was ground truthed to verify that the point was useable. Transects were then developed from these points because the derived GRTS point(s) only represented a location that was included within the transect; not a start, mid, or end point. Each year the transects were ground truthed again during the day and prior to the survey period due to constantly changing forest and road conditions to ensure routes were passable. This same method was also used in each deer hunting sub-unit (Figure 2) to calculate a sub-unit population estimate.

Spotlight surveys were conducted during the last two weeks of August. Transects were a minimum of 3.5 km with the greatest distance not exceeding 16 km. Distances were initially chosen based upon deer home range information (Pledger 1975, Marchinton and Hirth 1984, Nixon et. al. 1991). Deer are generally crepuscular (Marchinton and Hirth 1984, Beier and McCullough 1990); therefore, spotlighting began ½ hour after sunset and generally lasted 3-5 hours depending on transect length and deer observed. Spotlighting was not conducted in heavy rain, fog, or sleet as light could be obscured and deer activity tends to decline during these conditions (Hawkins, R.E., and Klimstra 1970, Micheal 1970, and Beier and McCullough 1990). On some occasions the survey could be paused (e.g., intermittent and light rain showers) and resumed once the inclement weather passed and on other occasions the survey was rescheduled. Temperature and wind speed were recorded at the beginning of surveys. Spotlights (two 4-million candle powered spotlights) were used to locate deer along transects. Each vehicle, generally a light-duty truck, contained two observers one of which was the driver. Observers searched both sides of the road. Vehicle speed was limited to ≤ 24 kph (15 mph). Observers were allowed to communicate with one another when a deer (or group) was located. Once deer were located the vehicle was stopped and observers identified species, sex, and group size using binoculars. A distance was recorded with the aid of a range finder at a 90-degree angle from the transect (road) to the location the deer were first spotted. Rangefinders were capable of 460 meters (500 yards) (Nikon rifle hunter and Nikon prostaff 7, Nikon, Shanghai, China). These data, along with a global positioning system (GPS) point, time and date, were recorded with a Trimble Juno (Trimble Navigation Limited, Sunnyvale, California) using Cybertracker data recording software (Cybertracker version 3.317, CyberTracker Conservation, Cape Town, South Africa).

Data were reviewed in ArcGIS 10.2 and each transect was overlaid with location points for deer groups. A vegetation layer from the U.S. Department of Agriculture, Forest Service (2014) was used to classify the entire Black Hills as either tree or meadow habitat. Portions of the U.S. Department of Agriculture, Forest Service layer were not defined by habitat type; those areas were manually defined by using satellite imagery also provided by U.S. Department of Agriculture, Forest Service (2009). Each transect was buffered by 300m and all lands within buffers were classified as tree or meadow habitat. Each transect was separated into smaller portions based on classification as tree or meadow habitat. These portions of meadow and tree habitat were then combined within transects to estimate transect length by habitat type.

Each deer data point was buffered by 300m in ArcGis using the aforementioned vegetation layer and white-tailed deer data points to establish if the data point primarily occurred in tree or meadow habitat. This information was then used to classify each white-tailed deer group as utilizing tree or meadow habitat. These data were then analyzed in Program Distance 6.0 (Thomas et. al. 2010) by clusters (i.e., groups) of deer in trees and in a separate analysis by clusters of deer in meadows with 95% confidence intervals. Program Distance also provided two separate estimates of density for each confidence interval for the entire area by deer cluster size (DS), and by density of deer in each km^2 (D). We used Markov Chain Monte Carlo (MCMC) (Metropolis et. al 1953, Hastings 1970) simulations in Program R (R Core Team 2015) (Figure 6.) to combine estimates and standard errors (SE) and derived a single and final population estimate with corresponding confidence intervals (CI). Density of deer (i.e. deer/km^2) from Program R outputs was calculated by dividing the output (n) by the total area (5,572.6 km^2) surveyed for Black Hills-wide estimates and for hunting unit estimates (unit 1 799.93 km^2, unit 2 2,280.79 km^2, unit 3 1,000.67 km^2, and unit 4 1,497.14 km^2) . Distance analyses were conducted on data collected each year of the study with Program Distance. Results were compared among years via overlap in 95% confidence intervals for annual mean density estimates.

Results

Pilot Study Results

Dawn$_2$ ($\bar{x}$ =12.6 deer/sampling time) surveys located more deer (t = 3.54, P = 0.018) than Dawn1 ($\bar{x}$ =10.4 deer/sampling time) surveys. Dusk$_2$ ($\bar{x}$ =14.8 deer/sampling time) surveys observed more deer (t = 3.392, P = 0.02) than Dusk$_1$ ($\bar{x}$ =10.6) surveys. Spot$_2$ ($\bar{x}$ 26.4 deer/sampling time) surveys located more deer (t = 2.936, P = 0.029) than Dusk$_2$ ($\bar{x}$ =14.8 deer/sampling time) surveys. Spot$_2$ ($\bar{x}$ =26.4 deer/sampling time) surveys also observed more (t = 3.353, P = 0.02) deer than Dawn$_2$ ($\bar{x}$ =12.6 deer/sampling time) surveys. There was no difference between Spot$_1$ ($\bar{x}$ =16.8 deer/sampling times) and Spot$_2$ ($\bar{x}$ =26.4 deer/sampling times) or Dawn$_2$ ($\bar{x}$ =12.6

deer/sampling times) and $Dusk_2$ ($\bar{x}$ =14.8 deer/sampling times) surveys. When comparing one versus two observers, two observer ($\bar{x}$ = 17.9 deer) surveys located significantly more deer (t = 4.974, P = 0.007) than one observer ($\bar{x}$ = 12.6 deer) surveys.

Total deer observed on each transect for every sampling event indicated that more deer where observed during two observer surveys with, as expected, the longest transect having the most deer overall (Table 1). We calculated total deer for each transect for one observer and two observer surveys and calculated that a minimum of 14.3% more deer were observed with two versus one observer surveys (Table 2). When comparing dawn and dusk surveys ($\bar{x}$ =13.7 deer/sampling time) with two observer spotlight surveys ($\bar{x}$ =26.4 deer/sampling time), there was a 96.4% increase in deer observed during spotlight surveys. For single observer surveys at dawn and dusk ($\bar{x}$ =10.5 deer/sampling time) compared to spotlight surveys ($\bar{x}$ =16.8 deer/sampling time) there was an 80% increase in the total deer observed (Table 1). The overall estimated density of deer in the survey area increased by 29.3% with two, compared to one observer surveys. Furthermore, single observer surveys had 16.0% more unknown sex and age deer than surveys conducted with two observers (Table 3). We evaluated mean time to sample transects (min/km) with one (5.0 min/km) and two observers (5.4 min/km) (Figure 8), which were similar.

Study

Using GRTS we initially sought to have 50 points selected as potential transect locations. After point and transect verification, 42 transects met requirements for use in estimating density of deer. The eight points that were not used were on major roads or interstate highways and, thus, were deemed too dangerous for use due to vehicle traffic. An additional year of data was collected in 2014 to ensure sufficient data to determine trend in deer population size and density. Also in 2014, additional transects were added to evaluate increase in precision of estimates. The number of additional 2014 transects was determined by randomly selecting transect data from 2012 and then 2013 and cumulatively summing values to estimate where the mean stabilized. A new GRTS sample was run to obtain 40 additional points to add to the previously used points and established transects. We removed many of these new points due to proximity to existing points/transects. We had assumed this would be the case so we ran our GRTS sample on a higher number of points (40) than we needed to obtain our objective of 20 additional independent points. We determined that transects greater than 16 km would cause logistical issues and a need to extend the survey period and/or require more personnel.

The main study analysis was performed on the deer group and not on the individual deer. The total length of road surveyed during 2012-2013 was 308.7 km and in 2014 we added an additional 170.6 km of roads for a total of 479.3 km. These extra transects were added in an effort to decrease confidence intervals and increase detection rates.

During August 2012, 108 white-tailed deer group observations (254 individuals) in meadows and 116 group observations (262 individuals) in trees were collected. Tree observations were comprised of 22.9% bucks, 47.7% does, 20.2% fawns, and 9.1% unknowns; meadow observations were comprised of 18.5% bucks, 58.26% does, 18.5% fawns and 5.9% unknown. Percentages of bucks, does, fawns, and unknown deer did not differ ($X^2 = 2.795$, df = 3, P = 0.424) between trees and meadows.

Based upon these results, Program Distance estimated 22,930 $\pm$ 5,450 (SE) white-tailed deer in meadows with a detection rate of 0.21 (Figure 16) and 31,227 $\pm$ 6,926 (SE) white-tailed deer in trees with a detection rate of 0.64 (Figure 17) for 2012 (Table 4). In 2012, counts of bucks, does, fawns, and unknown white-tailed deer approached significance (X^2 = 7.467, df =3, P = 0.058) when compared for the two habitats. Using MCMC simulations within Program R, a total estimate of 54,156 deer (95% CI=36,864-71,451, Figure 11) in 2012 was derived; white-tailed deer density was 9.7 deer/km² (95 % CI=6.6-12.8).

During August 2013, we collected 134 white-tailed deer group observations (301 individuals) in meadows and 144 white-tailed deer group observations (237 individuals) in trees. Of these, observations were comprised of 17.2% bucks, 60.7% does, 12.9% fawns, and 8.9% unknowns in meadows; tree observations were comprised of 31.2% bucks, 46.4% does, 17.2% fawns and 5.0% unknowns. In 2013, Program Distance was used and estimated 18,720 ± 3,390 (SE, Table 4) white-tailed deer in meadows with a detection rate of 0.13 (Figure 18) and 18,838 ± 4,042 (SE, Table 4) white-tailed deer in trees with a detection rate of 0.45 (Figure 19). When using MCMC simulations within Program 2013 white-tailed deer estimates were 35,557 (95 % CI=27,200-47,907, Figure 11) for the Black Hills; white-tailed deer density was 6.7 deer/km² (95% CI=4.88-8.59).

In August of 2014, using the 42 transects, we observed 129 white-tailed deer groups (270 individuals) in meadows and 147 white-tailed deer groups (268 individuals) in trees. Composition included 20.0% bucks, 53.3% does, 14.0% fawns and 12.6% were unknown; trees percentages were 22.3% bucks, 49.2% does, 15.2% fawns and 13.0% unknown. Percentages of bucks, does, fawns, and unknown deer did not differ (X^2 = 0.327, df = 3, P = 0.955) between tree and meadow habitats. Program Distance estimates were 23,050 ± 5,327 (SE, Table 4) deer in meadows with a detection rate of 0.38 (Figure

20) and 20,850 ± 3,584 (SE, Table 4) deer in trees with a detection rate of 0.11 (Figure 21). These two estimates were again combined using MCMC simulations in Program R for a total Black Hills-wide estimate of 43,899 white-tailed deer (95% CI=31,316-56,491, Figure 11); white-tailed deer density was estimated at 7.8 deer/km² (95% CI=5.6-10.1).

To evaluate increase in precision for the 2014 estimate we added 20 additional transects to the original 42 transects which increased counts to 157 white-tailed deer groups (332 individuals) observations in meadows and 220 white-tailed deer groups (392 individuals) observations in trees. Composition in meadows were, 19.5% were bucks, 53.3% does, 13.8% fawns, and 13.2% were unknown; in trees 21.1% were bucks, 49.2% were does, 16.3% were fawns, and 13.2% were unknown. Percentages of bucks, does, fawns, and unknown deer did not differ ($X^2 = 0.562$, df = 3, $P = 0.905$) between tree and meadow habitats. Program Distance estimated 23,208 ± 4,648 (SE, Table 4)) deer in meadows with a detection rate of 0.40 (Figure 17) and 18,670 ± 2,695 (SE, Table 4) deer in trees with a detection rate of 0.10 (Figure 23). Using MCMC simulations in Program R, total population for the Black Hills was estimated at 41, 866 (95% CI=31,352-52,423, Figure 11) white-tailed deer; density was estimated at 7.5 deer/km² (95% CI=5.6-9.4). Individual deer management unit estimates were derived for meadows and trees using portions of transects located within those units for each year that surveys were conducted (See Chapter 1 for unit descriptions). The original 42 transects used for the entire Black Hills were utilized for each management unit and each management unit contained the following number of transects: Unit 1-10 transects, Unit 2- 32 transects, Unit 3 – 9 transects and Unit 4 -11 transects.

These estimates of white-tailed deer density were run individually as tree or meadow habitat in Program Distance and then combined in Program R for a total management unit (habitat) estimate. In 2012, meadow estimates for total white-tailed deer from Program Distance were: Unit 1 =1,206 (95% CI=527-2,760); Unit 2 = 4,387 (95% CI=2,294-8,389); Unit 3 = 9,385 (95% CI=17-5,123,100); and Unit 4 = 12,330 (95% CI= 5,238-29,024). Estimates for total white-tailed deer in tree habitat by management unit were as follows: Unit 1 = 1,278 (95% CI= 361-4,523); Unit 2 = 12,307 (95% CI=8,403-18,025); Unit 3 = 3,483 (95% CI=1,254-9,676); and Unit 4 = 10,252 (95% CI= 4,886-21,508, Table 4). Program R output combining the meadow and tree estimates for total white-tailed deer using MCMC simulations was: Unit 1 = 2,483 (95% CI=729-4,238, Figure 12.); Unit 2 = 16,695 (95% CI=11,337-22,052, Figure 13); Unit 3 = 12,876 (95% CI= 4,171 – 29,915, Figure 14); and Unit 4 = 22,593 (95% CI=10,481-34,684, Figure 15). White-tailed deer density calculated from Program R output was: Unit 1 = 3.1 (95% CI=0.91-5.30 deer /km^2); Unit 2 = 7.3 (95% CI=4.97-9.66 deer /$km^{2)}$; Unit 3 = 12.9 (95% CI= -4.17-29.89 deer /km^2); and Unit 4 = 15.1 (95% CI=7.0-23.16 deer /km^2).

Data collected in August 2013 was used to derive management unit estimates. Program Distance outputs for total white-tailed deer in meadows were: Unit 1 = 1,460 (95% CI=89-23,960); Unit 2 = 6,639 (95% CI=4,192-10,515); Unit 3 = 11,227 (95% CI=6,089-20,700); and Unit 4 = 4,302 (95% CI=1,677-11,037). In 2013, total white-tailed deer in trees were: Unit 1 = 1,997 (95% CI=40-99,331); Unit 2 = 7,695 (95% CI=4,840-12,236); Unit 3 = 3,483 (95% CI=1,254-9,676); and Unit 4 = 7,351 (95% CI=3,184-16,969, Table 4). Estimates from MCMC simulations in Program R for total white-tailed deer resulted in the following outputs: Unit 1 = 3,459 (95% CI=-372-7,297, Figure 12); Unit 2 = 14,336 (95% CI=9,798-18,873, Figure 13); Unit 3 = 14,710 (95% CI=7,799-21,614, Figure 14); and Unit 4 = 11,650 (95% CI= 5,168-18,124, Figure 15). White-tailed deer densities were: Unit 1 = 4.3 deer /km^2 (95% CI=-0.47-9.12 deer /km^2); Unit 2 = 6.3 deer /km^2 (95% CI= 4.30-8.27 deer /km^2); Unit 3 = 14.7 deer /km^2 (95% CI= 7.79-21.60 deer /km^2) and Unit 4 =7.8 deer /km^2 (95% CI= 3.45-12.11 deer /km^2).

In 2014, meadow estimates for total white-tailed deer for management units were: Unit 1 = 1,539 (95% CI=711-3,332); Unit 2 = 6,994 (95% CI=4,306-11,358); Unit 3 = 6,027 (95% CI=1,820-19,962); Unit 4 = 12,562 (95% CI=2,926-53,937). In 2014, estimates for total white-tailed deer in trees were: Unit 1 = 1,273 (95% CI=284-5,719); Unit 2 = 8,842 (95% CI=6,025-12,975); Unit 3 = 3,631 (95% CI=1,079-12,218); and Unit 4 = 8,184 (95% CI=2,805-23,881, Table 4). MCMC simulations from Program R resulted in the following estimates for total white-tailed deer: Unit 1 = 2,811 (95% CI=974-4,647, Figure 12); Unit 2 = 15,838 (95% CI=11,217-20,457, Figure 13); Unit 3 = 14,713 (95% CI=7,818-21,614, Figure 14); and Unit 4 = 20,760 (95% CI=4,776-36,717, Figure 15). White-tailed deer densities for the defined units were: Unit 1 = 3.5 (95% CI=1.27-5.80 deer /km^2); Unit 2 = 6.9 (95% CI=4.91-8.96 deer /km^2); Unit 3 = 14.7 (95% CI=7.81-21.59 deer /km^2) and Unit 4 = 13.8 (95% CI=3.19-24.52 deer /km^2).

In 2014, estimates of total white-tailed deer using all transects (n=62) in meadows were: Unit 1 = 1,539 deer (95% CI=711-3,332); Unit 2 = 7,294 (95% CI=4,848-10,973); Unit 3 = 6,027 (95% CI=1,820-19,962); Unit 4 = 9,886 (95% CI=3,754-26,031). In 2014, using all transects (n=62) for white-tailed deer in trees were: Unit 1 = 2,340 (95% CI=1,152-4,755); Unit 2 = 8,111 deer (95% CI=5,119-12,853); Unit 3 = 7,726 (95%

CI=3,376-17,681); and Unit 4 = 7,726 deer (95% CI=3,376-17,681, Table 4). Estimates for total white-tailed deer occupying the defined units were Unit 1 = 3,877 (95% CI=1,930-5,828, Figure 12); Unit 2 = 15,403 (95% CI=10,687-20,133, Figure 13); Unit 3 = 8,636 (95% CI=2,149-15,106, Figure 14); and Unit 4 = 17,604 (95% CI=7,724-27,494, Figure 15). White-tailed deer densities were: Unit 1 = 4.8 (95% CI=2.41-7.28 deer /km^2); Unit 2 = 6.7 (95% CI=4.68-8.82 deer /km^2); Unit 3 = 8.6 (95% CI=2.14-15.09 deer /km^2); and Unit 4 = 11.7 (95% CI=5.15-18.36 deer /km^2).

Discussion

Wildlife managers are constantly struggling with cost versus benefit ratios of surveys applied to white-tailed deer populations in the United States (Collier 2013). Spotlight road surveys have shown bias (Anderson et al. 1979, Burnham et al. 1980, Anderson 2001, Pollock et al. 2002, Ellingson and Lukacs 2003, Sauer et al. 2005) generally due to non-random sampling methods. Spotlight surveys have been known to result in inaccuracies relative to age and sex classifications with biases towards females (McCullough 1982, Fafarman and DeYoung 1986). Hunted populations display skewed sex ratios as hunters tend to select for males and/or regulations may restrict harvest of females (Dusek et al. 1989, Nixon et al. 1991, Van Deelen et al. 1997, Jenks et al. 2002). We did not estimate a sex ratio, it can be assumed that white-tailed bucks would be detected less frequently than either does or fawns due to the Black Hills being a hunted population.

Whipple (1994) noted that depending on canopy cover, deer density can be over or underestimated. Koenen et al. (2002) warned against using distance sampling from roads in areas that lacked extensive road networks, had high vegetation density/visual obstruction, and did not have uniform topography. The Black Hills National Forest (BHNF) is one of the most heavily roaded national forests with 13,411 km of inventoried roads within and adjacent to the BHNF boundary (United States Department of Agriculture [USDA] Forest Service 2007). The forest roads were primarily constructed in riparian bottoms and areas with more open habitat structure, therefore some of the warnings by Koenen (2002) were not entirely applicable to the BHNF.

McCullough (1982) found deer could be spotlighted equally well in grasslands, hardwood forests, or marshes. Roads in the Black Hills are pervasive and the majority of the Black Hills is accessible by road. We used a GRTS technique to select transects that gave us a representative sample of the entire Black Hills of South Dakota (Figure 10) while adhering to the constraints of white-tailed deer home range size. The Black Hills, although approximately 71% forest, is quite variable in vegetation density and topographical relief. Our approach to separate estimates by habitat type allowed for analyses that met assumptions of distance sampling (Buckland et al. 2001) which were: 1. objects on the transect were always detected, 2. objects were detected at their initial location and 3. Distances were measured accurately. Based upon meeting the assumptions of Program Distance, undetected animals were accounted for and unbiased estimates were derived.

We questioned why 2013 estimates were lower than 2012 and 2014. Our confidence intervals do overlap suggesting that all years have a similar population number however reasoning for the drop in population estimates for 2013 was sought. In 2012 and 2014 deer were being seen at greater distances (200 m and greater) and non-uniform distributions of distances per each sample were recorded thus producing varied detection rates. Adding transects, as we did in 2014, aided to improve precision of the estimate by lowering confidence intervals.

We questioned our methodology of spotlight surveys in the Black Hills and other methods of surveying were feasible but they too have their drawbacks and associated costs. It has been found that similar results can be expected from forward looking infrared (FLIR, Belant 2000) when comparing to spotlight counts and other methods have sought to slightly modify the spotlighting technique to evoke a higher detection rate (Cypher 1991). Given the wide variety of choices and modifications we concluded that our study was best suited to traditional style of spotlight counts for not only cost but ease of use. To our knowledge, no previous literature was available on the coupled use of spotlighting, distance sampling, and GRTS techniques. Thus, our approach was unique regarding estimating deer populations in forested systems.

Density estimates using varying spotlighting methods have produced variability in similar vegetation and habitat types. Gunson (1979) found in his spotlight study there were 0.9 deer/km^2 in Alberta and 0.1 deer/km^2 in Saskatchewan. In areas with less forest cover, Stainbrook (2012) found density estimates ranged from 43-71 deer/km^2 using multiple spotlighting methods during various times of year. Sage (1983) observed 3-10 deer/km^2 in forested habitat in New York. In the Black hills, two studies were previously conducted to estimate deer density; they observed 1.6 deer/km (Kranz 1974) and 11.0 deer/km^2 (Progulske and Duerre 1964). However, these two studies were limited in sample size, were performed on a select few roads or, in the case of Progulske and Duerre (1964), were based in meadows and agricultural fields. Therefore, these studies are of limited value as they are not representative of the true deer population occupying the region (Anderson 2001). In comparison, our study found 8.9 deer/km^2 in 2012, 6.7 deer/km^2 in 2013, 9.5 deer/km^2 = in 2014 and 9.0 deer/km^2 in 2014 with the addition of the 20 transects. Our overall mean for the three years, not including 2014 with the additional routes was 8.4 deer/km^2. In comparison, SDGFP estimated 8.1 deer/km^2 in the Black Hills as derived from 2014 population estimates (SDGFP 2015).

Our overall population estimate results were similar to estimates provided from SDGFP big game reports for all years of this study (2012 N=38,050; [95%CI=27,768-48,332]; 2013 N=41,200 [CI=29,600-52,800]; 2014 N=45,055 [CI=31,695-58,415]; South Dakota Department of Game Fish and Parks 2013, 2014, 2015). Overlapping confidence intervals between estimates suggests the estimates are similar (Johnson 1999). However, individual unit estimates were variable most likely due to unit size and habitat type, which vary across the Black Hills. Although our estimates had wide confidence intervals, our data likely reflects the characteristics of the Black Hills. Nevertheless, confidence interval overlap indicated that the results were similar for management units, thus, more information is necessary to validate unit level population estimate variability within the Black Hills region. Unit estimates for white-tailed deer were derived from samples taken during the Black hills wide survey. However, constraints of individual unit size and home range of white-tailed deer limited options for increasing independent sample sizes and ultimately affected management unit analysis.

Dasmann and Taber (1956) stated that deer are most accurately counted and classed during times of year when family groups are present and not any one class is misrepresented, which they eluded to being in July and December in coastal California. Observability bias also has been shown in populations where true sex and age class ratios were known (Dowing et al. 1977, McCullough 1982, Sage et. al. 1983, McCullough and Hirth 1988). Our results indicated percentages of bucks, does, and fawns were variable, which has been documented in previous studies in other areas (Progulske and Duerre 1964, Conolly 1981, McCullough 1982, McCullough and Hirth 1988, Garcia 1989). McCullough (1993) stated that deer showed less alarm behavior during night spotlight counts, which could positively influence sex ratios. Although our age and sex ratios were variable, counts of bucks, does, and/or fawns spotted during this survey did not differ from meadows or trees which would indicate they are distributed equally across habitats. These findings align with the 1950 and 1970 spotlight surveys conducted by SDGFP in the Black Hills. The fact that all classes were equally distributed across all habitat types further justifies using spotlight counts as a means for a population estimate in the Black Hills of South Dakota.

Management Implications

Our pilot study indicated that data collected with two observers during spotlight surveys was optimal for deer detection; thus, future surveys should use two observers. Our primary study findings indicate an overall population estimate and an index to population density can be derived on an annual basis using similar methods as ours. We recommend that data should be collected annually to determine a population trend which would be beneficial to game managers. We believe using a multiple year moving average could provide a suitable estimate that could be utilized in population models. Our confidence intervals for Black Hills-wide estimates were large due to the habitat and topographical variability characteristic of the region. However, overlapping confidence intervals for each year indicate similar populations through those three years. When increasing sample size by adding transects, variation in estimates was not reduced, which indicated that this inherent variability was pervasive and thus, further attempts to reduce variability would not be beneficial. However, additional transects provided improved population estimates via detection rates becoming more uniform. Therefore, using a similar number of transects as we did in 2014 would be most beneficial to future survey protocols. Due to a dynamic forest ecology and deer movement patterns, groups detected at distances over 300 m should not be collected as results may be skewed by program Distance and the interpretation of the detection rate. It is also recommended to follow our protocol for survey period, the last two weeks of August, and survey length, within a 2-week period from the beginning of the survey to ensure comparable results from year to year.

Unit density estimates provided wide confidence intervals due to low transect availability. There is no way to properly increase sample size that would satisfy our methodology and maintain data credibility. The size of defined management units prohibit the use of GRTS methodology for transect selection because transects start crossing one another or lay close enough in proximity to one another that double sampling of deer may occur. Therefore, sampling and deriving population estimates at the unit level is not recommended.

Lastly, transects should be driven before the survey period begins to ensure transects are accessible. It would be recommended that routes be maintained wherever possible to provide comparable results from year to year. This could be done by selecting only roads, pre-GRTS, that are of a higher USFS classification which would be accessible for the foreseeable future. If roads are lost due to closures, new transects should be derived to compensate for the reduction of survey transects.

Chapter 3

DEER HERD COMPOSITION: AGE AND SEX RATIOS

Introduction

Sex and age ratios of white-tailed (*Odocoileus virginianus*) and mule deer (*O. hemionus*) are important demographic parameters useful for understanding population ecology and managing these highly sought after big game animals. South Dakota Department of Game, Fish and Parks (SDGFP) currently uses harvest estimates, spring aerial counts, survival data, and herd composition surveys to assess the population status of these species. Many western states, including South Dakota, utilize herd composition counts (HCC) for sex (Buck:Doe) and age (Fawn:Doe) ratio information (Rabe et al. 2002). HCC surveys in South Dakota currently take place from 1 September to 31 October annually. Sample size requirements and time frame as surveys relate to detection of bucks, does, and fawns, however, has been questioned. For example, HCC have shown high variability and low precision (Conolly 1981, McCullough 1982, McCullough and Hirth 1988, Garcia 1989) and thus, their use has been criticized (Caughley 1974, Caughley 1977, McCullough 1994). Despite potential issues with HCC, they are still utilized to determine population growth rates (Downing 1980) and estimate recruitment (McCullough 1994). It has been argued that HCC are an important indicator in population assessment (Engman 2003) and if applied properly they can be of great use in management (Bender 2006). Conversely, it has been argued that without estimates of detection probabilities, HCC are not reliable (Anderson 2001, Anderson 2003).

Aerial herd counts can be an effective method for classifying large species in open landscapes (Pojar et al 1995, Rabe et al. 2002, Kaji 2005), but when habitats are dense, expense rises and efficacy decreases (Kaji 2005). Variability has been documented in ground counts of various ungulate species including white-tailed and mule deer (McCullough 1993, McCullough et al. 1994, Taber et al. 1982, Kaji 2005). Many studies have been conducted that evaluated use of HCC for deer but none have addressed their use on a wide geographic scale encompassing a diversity of habitats and differences in topographic relief (Downing 1977, McCullough 1993, McCullough 1994, Kaji 2005). Aerial classification on this wide a geographic scale would be too costly and labor intensive to conduct. Our objectives for this study were: 1) determine minimum sample size of deer for HCC, 2) compare September and October counts for estimating HCC, 3) assess feasibility of obtaining male: female (sex) ratios from deer survey data, 4) compare spotlight and daylight counts for estimating HCC, and 5) evaluate effects of a) counting all deer observed vs. only conclusive counts, b) distance from cover, and c) number of observers.

Methods

White-tailed deer are found statewide while mule deer are primarily located west of the Missouri River; therefore, in counties west of the Missouri River (WR) both species were identified and counted whereas east of the Missouri River (ER), only white-tailed deer were counted (see Chapter 1 for study area descriptions). All deer observed regardless of age, sex, or species were counted in separate study areas (see Chapter 1 for study area information). Daylight and spotlight surveys were conducted 1-15 September and 15-31 October in study areas in 2012 and 2013. These time frames were chosen to maximize personnel, allow sufficient time between the two survey months for survey completion before the hunting season, to coincide with current SDGFP herd composition survey dates, and to allow time to conduct the second half of the scheduled pronghorn (*Antilocapra americana*) classification survey (see Chapter 4).

Deer generally exhibit crepuscular behavior patterns (Marchinton and Hirth 1984, Beier and McCullough 1990); therefore, daylight surveys were defined as ½ hour before sunrise and preceding no more than 2 hours after sunrise, and 2 hours before sunset to ½ hour after sunset. No fog or rain during the survey was acceptable as deer activity tends to decline during these weather conditions (Hawkins and Klimstra 1970, Micheal 1970, Beier and McCullough 1990); surveys were conducted under variable cloud cover. One observer who counted all deer observed on either side of the transect (i.e., road) was standard methodology for day time surveys. Distance from cover was recorded using a rangefinder capable of 500 m (Nikon rifle hunter and Nikon prostaff 7, Nikon Inc. Melville, New York, USA). When deer were observed, we collected information on behavior of the deer (standing, running, bedded), habitat type (cattail (*Typha* sp.) wetlands, crop stubble, short crop, short grass, tall crop, tall grass, trees, wooded riparian, and other); distance from cover in increments of 10 m to 50 m and > 50 m; cloud cover (0-25%, 25%-50%, 50%-75% and 75%-100%); an assessment of topographic impediments to the observed group; and a response to the question "do you believe the count was complete? (yes, no, maybe)". Data (with GPS point, time, and date) were recorded with a Trimble Juno **(**Trimble Navigation Limited, Sunnyvale, California, USA, 94085) using Cybertracker data recording software (Cybertracker version 3.317, Cybertracker conservation, Noordhoek, Cape Town, South Africa).

Spotlight surveys began ½ hour after sunset and generally lasted 3-5 hours depending on route length and number of deer observed (Anderson 1959, Montgomery

1963, Progulske and Duerre 1964, McCaffery and Creed 1969). No set transect (route) was traveled; however, each sighting was mapped via Cybertracker to determine area surveyed to reduce the probability of redundant sampling. White-tailed deer were the only species counted during the spotlight survey. Mule deer were not generally found in the study areas we spotlighted but if they were seen during a spotlight count they were counted but those data were removed from the spotlight analysis. Spotlighting was not conducted in heavy rain or sleet, which would obscure the spotlight (McCullough 1982). If these conditions presented themselves mid survey the survey was ended. On some occasions the survey could be paused and resumed once the weather improved (if the weather improved in $\leq$ 10 minutes and was not severe). A maximum vehicle speed of 32 KMH (20 MPH) was implemented to ensure observers had sufficient time to locate deer during surveys. Temperature and wind speed were recorded at the beginning of the survey. Each route was lighted using two cyclops seeker hand held 4 million candle powered spotlights (Cyclops Seeker, Good Sportsman Marketing, Grand Prairie, TX, USA). Each vehicle contained two observers one of which was the driver and observers were allowed to communicate when deer were observed. Once deer were observed, the vehicle was stopped and observers identified species, sex, and group size using binoculars. Distance to deer was estimated with the aid of a range finder at a 90-degree angle from the transect (road). All data were recorded using a Trimble Juno GPS unit coupled with the program Cybertracker.

Data analysis

We generated sample size goals annually that were derived from the previous year's harvest numbers (South Dakota Game, Fish and Parks 2012,2013) using a standard sample size formula (Zar 1999). Data were analyzed based upon age and sex ratios for each species by daytime and spotlight counts comparing: months, habitat types, time observations took, topographical obstruction, deer distance from cover, and completeness of count. Data for comparison of months for age and sex ratios for daylight and spotlight counts for both species was analyzed using 2-tailed t-tests assuming unequal variances with an alpha level of 0.05. All pooled data were analyzed by single factor ANOVA with an alpha level of 0.05. Differences were considered statistically different when $P < 0.05$. Pooled data for time was quantified using two methods; either between 0-3 minutes and longer than 3 minutes and 0-1 minute and above 1 minute for both age and sex ratios. Catch per unit effort (CPUE) was calculated using starting and ending survey times based upon number of deer counted for either species from 2013; 2012 was not calculated as neither, a start or end time was documented.

When calculating sex ratios, the proportion of bucks to does was calculated using a proportions formula (adult bucks/ (adult bucks + adult does)) (P. Lukacs, Montana State University, personal communication). This equation was not used for our age ratios (fawns: adult does) because it was rare fawns are observed without does; however, bucks were generally seen in bachelor groups without does.

Results

During daylight counts we counted 8,841 white-tailed deer (1,483 bucks, 4,078 does, and 2,920 fawns) in all study areas for both months in 2012. We counted 5,674 white-tailed deer (817 bucks, 2,893 does and 1,964 fawns) in all study areas for both months in 2013. Two-thousand seven hundred and ninety-nine mule deer (618 bucks, 1,393 does, and 788 fawns) were counted in 2012 in all study areas where mule deer were observed; in 2013 we counted 1,514 mule deer (317 bucks, 765 does and 432 fawns) in all study areas. During spotlight counts 3,423 white-tailed deer (642 buck, 1,643 does and 1,138 fawns) were identified in 2012; in 2013, we counted 4,508 white-tailed deer (783 bucks, 2,527 does and 1,198 fawns).

Sample Size

At the beginning of the survey, we based our sample size requirements on a minimum sample size formula (Czaplewski 1983), which incorporated previous herd composition data, survival rates, and harvest data. Our initial goal for sample size was between 60 and 70 observations per year for each separate study area. After the survey, results indicated that a minimum of 60 to 70 counts (Table 5) were necessary to reach the threshold where the age ratio stabilized. This threshold sample size for stabilization was consistent across years and months.

White-tailed Deer Age Ratios

We pooled date for both years for age ratio counts determined from daylight counts; we compared ratios by month, habitat type, time of observations, topographical obstruction, and deer distance from cover. Completeness of count methods were altered between years; therefore, each year was reported separately. Age ratios calculated from daylight counts did not differ between September and October ($P = 0.13$, Table 6) for white-tailed deer. Comparison of age ratios of white-tailed deer by habitat type also did not differ ($P = 0.54$, Table 7). Furthermore, white-tailed deer age ratios calculated relative to distance from cover did not differ ($P = 0.42$, Table 8). We evaluated observation time using two time categories for daylight white-tailed deer age ratios. Our first observation time categories for comparison were 0 to 1 minute and 1 minute and greater; ratios calculated from these data did not differ ($P > 0.05$) from one another (Table 9). Our second-time categories, 0 to 3 minutes and 3 minutes and greater, also did not differ (P > 0.05) between one another (Table 10). Comparison of the potential effect of topographical obstruction upon white-tailed deer age ratios differed ($P \leq 0.001$) between "yes" (i.e., there was an effect, $\bar{x}$ = 0.63) and "no" (i.e., there was no effect, $\bar{x}$ = 0.78, Table 11). Our question of completeness of count for 2012 ($P \leq 0.001$) differed between "maybe" ($\bar{x}$ = 0.70), "yes" ($\bar{x}$ =0.83), and "no" ($\bar{x}$ = 0.61, Table 12). Our question of completeness of count for 2013 also differed ($P \leq 0.001$) for age ratios between "yes" ($\bar{x}$ = 0.81) and "no" ($\bar{x}$ = 0.48, Table 13) responses.

Spotlight count data also was pooled across years to compare white-tailed deer age ratios by month, habitat type, time of observations, topographical obstruction, and deer distance from cover. Completeness of count again was altered between years; therefore, results for each year are reported separately. No difference (P = 0.81) was noted between age ratios for surveys where observers answered "yes" ($\bar{x}$ = 0.69) and those where observers answered "no" ($\bar{x}$ = 0.70) for topographical obstruction (Table 14) of white-tailed deer observations. Comparison of white-tailed deer age ratios as they relate to distance from cover differed ($\bar{x}$ = 0.01) with farther ranges, 50+ meters, having a higher mean ratio ($\bar{x}$ = 0.80) than 0 to 50 meters ($\bar{x}$ = 0.69, Table 15). We evaluated observation time as with daylight counts using two different time category pairs for age ratios generated from spotlight counts of white-tailed deer. Our first observation time categories for comparison, time 0 to 1 minute and 1 minute and greater, did not differ (P > 0.05) between one another (Table 16). Our second-time categories for comparison, 0 to 3 minutes and 3 minutes and greater, also did not differ (P > 0.05) between one another (Table 17). Our question of completeness of the spotlight count for 2012 for white-tailed deer age ratios ($P \leq 0.001$) differed between "maybe" ($\bar{x}$ = 0.54), "yes" ($\bar{x}$ = 0.77) and "no" ($\bar{x}$ = 0.59, Table. 18). Our question of completeness of count for 2013 also differed (P $\leq$ 0.001) for age ratios between "yes" ($\bar{x}$ = 0.77) and "no" ($\bar{x}$ = 0.42, Table 19) responses. Comparison of months also differed (P $\leq$ 0.001) indicating that October ($\bar{x}$ = 0.85) had a higher age ratio than did September ($\bar{x}$ = 0.56, Table 20). Lastly, our comparison age ratios as they related to habitat types differed (P $\leq$ 0.001) from one another; we found short grass had a higher mean age ratio ($\bar{x}$ = 0.84) than all other habitat categories (Table 21).

We compared pooled data for both months for daylight counts to both months of spotlight counts and found counts did differ (P = 0.003) with daylight count age ratios having a higher mean ($\bar{x}$ = 0.77) than spotlight counts ($\bar{x}$ = 0.70, Table 22). Age ratios derived from daylight counts for September were compared to spotlight age ratios in September and they differed (P $\leq$ 0.001) with daylight age ratios having a higher mean ($\bar{x}$ = 0.76) than age ratios from spotlight counts ($\bar{x}$ = 0.56, Table 23). Daylight age ratios for October ($\bar{x}$ = 0.77) were compared to October spotlight age ratio counts ($\bar{x}$ = 0.85); ratios differed (P = 0.02, Table 24) from one another.

Mule Deer Age Ratios

Data were pooled for both years for mule deer age ratio counts determined from daylight counts; we compared ratios by month, habitat type, time of observations, topographical obstruction, deer distance from cover and completeness of count. Completeness of count methods were altered between years; therefore, each year was reported separately. Mule deer age ratios calculated from daylight counts did not differ (P = 0.36) between September ($\bar{x}$ = 0.62) and October ($\bar{x}$ = 0.66, Table 25). Comparison of age ratios of mule deer by habitat type also did not differ (P = 0.78, Table 26). We evaluated observation time using two time categories for mule deer age ratios. Our first observation time categories for comparison were 0 to 1 minute ($\bar{x}$ = 0.70) and 1 minute and above ($\bar{x}$ = 0.61); ratios calculated from these data did not differ (P = 0.07) from one another (Table 27). Our second-time categories, 0 to 3 minutes ($\bar{x}$ = 0.64) and 3 minutes and above ($\bar{x}$ = 0.61), also did not differ (P = 0.53) between one another (Table 28). Comparison of topographical obstruction based upon mule deer age ratios did not differ (P = 0.60) between "yes" ($\bar{x}$ = 0.62) and "no" ($\bar{x}$ = 0.64, Table 29). Furthermore, mule deer age ratios calculated relative to distance from cover did not differ (P = 0.63) for either the 0 to 50-meter category ($\bar{x}$ = 0.63) or the 50+ category ($\bar{x}$ = 0.66, Table 30).

Our question of completeness of count for 2012 (P = 0.42) did not differ between "maybe" ($\bar{x}$ = 0.54), "yes" ($\bar{x}$ = 0.63) and "no" ($\bar{x}$ = 0.65, Table 31). Our question of completeness of count for 2013 differed (P = 0.02) between "yes" ($\bar{x}$ = 0.71) and "no" ($\bar{x}$ = 0.48, Table 32).

White-tailed Deer Sex Ratios

Data were pooled for both years for sex ratio counts determined from daylight counts; we compared ratios by month, habitat type, time of observations, topographical obstruction, and deer distance from cover. Completeness of count methods were altered between years; therefore, each year was reported separately. Sex ratios calculated from daylight counts differed (P = 0.001) between September ($\bar{x}$ = 0.17) and October ($\bar{x}$ = 0.21, Table 33) for white-tailed deer.

Comparison of sex ratios of white-tailed deer by habitat type also did not differ (P = 0.43, Table 34). We evaluated observation time using two time categories for daylight white-tailed deer sex ratios. Our first observation time categories for comparison were 0 to 1 minute ($\bar{x}$ = 0.20) and 1 minute and greater ($\bar{x}$ = 0.19); ratios calculated from these data did not differ (P > 0.05) from one another (Table 35). Our second-time categories, 0 to 3 minutes ($\bar{x}$ = 0.19) and 3 minutes and greater ($\bar{x}$ = 0.20), also did not differ (P > 0.05) between one another (Table 36). Comparison of topographical obstruction based upon white-tailed deer sex ratios were similar (P = 0.11) between data collected when survey crews answered “yes” ($\bar{x}$ = 0.21) and “no” ($\bar{x}$ = 0.19, Table 37) regarding potential for obstruction. White-tailed deer sex ratios calculated relative to distance from cover did not differ (P = 0.33, Table 38). Our question of completeness of count for 2012 was similar (P = 0.29) between “maybe” ($\bar{x}$ = 0.0.18), “yes” ($\bar{x}$ = 0.21) and “no” ($\bar{x}$ = 0.20, Table 39). Our question of completeness of count for 2013 also was similar (P= 0.15) for sex ratios between data for “yes” ($\bar{x}$ = 0.16) and “no” ($\bar{x}$ = 0.19, Table 40) questions.

Spotlight count data also was pooled across years to compare white-tailed deer sex ratios by month, habitat type, time of observations, topographical obstruction, and deer distance from cover. Completeness of count again was altered between years; therefore, results for each year are reported separately. No difference (P = 0.40) was noted between sex ratios for surveys where observers answered “yes” ($\bar{x}$ = 0.26) and those where observers answered “no” ($\bar{x}$ = 0.24) for topographical obstruction of white-tailed deer (Table 41). Comparison of white-tailed deer sex ratios as they relate to distance from cover were similar (P = 0.52) for our 50+ meter category ($\bar{x}$ = 0.024) and our 0 to 50-meter category ($\bar{x}$ = 0.26, Table 42). Our comparison of sex ratios as they related to habitat types differed (P $\leq$ 0.001) from one another; we found those generated for data in short grass ($\bar{x}$ = 0.18), cattails ($\bar{x}$ = 0.20), and crop stubble ($\bar{x}$= 0.24) had lower means than all other habitat categories (Table 43).

We evaluated observation time as was done with daylight counts using two different time category pairs for sex ratios generated from spotlight counts of white-tailed deer. Our first observation time categories for comparison, time 0 to 1 minute ($\bar{x}$ =0.35) and 1 minute and greater ($\bar{x}$ = 0.22) differed (P $\leq$ 0.001) between one another (Table 44). Our second-time categories for comparison, 0 to 3 minutes ($\bar{x}$ = 0.27) and 3 minutes and great ($\bar{x}$ = 0.18), also differed (P $\leq$ 0.001) from one another (Table 45).

Our question of completeness of spotlight counts for 2012 white-tailed deer sex ratios differed (P = 0.002) between “maybe” ($\bar{x}$ = 0.20), “yes” ($\bar{x}$ = 0.27) and “no” ($\bar{x}$ = 0.14, Table 46). Our question of completeness of count for 2013 also differed (P $\leq$ 0.001) between “yes” ($\bar{x}$ = 0.28) and “no” ($\bar{x}$ = 0.19, Table 47). Comparison of months also differed (P = 0.02) indicating that October ($\bar{x}$ = 0.27) had a higher sex ratio than September ($\bar{x}$ = 0.24, Table 48). We compared pooled data for months for daylight counts and spotlight counts and found counts did differ (P $\leq$ 0.001) with daylight count sex ratios ($\bar{x}$ = 0.17) lower than spotlight counts ($\bar{x}$ = 0.26, Table 49). Sex ratios derived from daylight counts for September ($\bar{x}$ = 0.12) were compared to spotlight sex ratios in September ($\bar{x}$ = 0.24) and they differed (P $\leq$ 0.001, Table 50). Daylight sex ratios for October ($\bar{x}$ = 0.21) were compared to October spotlight sex ratio counts ($\bar{x}$ = 0.27); ratios differed (P $\leq$ 0.001, Table 51) from one another.

Mule Deer Sex Ratios

Data were pooled for both years for mule deer sex ratio counts determined from daylight counts; we compared ratios by month, habitat type, time of observations, topographical obstruction, deer distance from cover and completeness of count. Completeness of count methods were altered between years; therefore, each year was reported separately. Mule deer sex ratios calculated from daylight counts did not differ (P = 0.05) between September ($\bar{x}$ = 0.26) and October ($\bar{x}$ = 0.31, Table 52). Comparison of sex ratios of mule deer by habitat types also did not differ (P = 0.80, Table 53). We evaluated observation time using two time categories for mule deer sex ratios. Our first observation time categories for comparison were 0 to 1 ($\bar{x}$ = 0.32) minute and 1 minute and greater ($\bar{x}$ = 0.27); ratios calculated from these data did not differ (P = 0.12) from one another (Table 54). Our second-time categories, 0 to 3 minutes ($\bar{x}$ = 0.29) and 3 minutes and greater ($\bar{x}$ = 0.24), also did not differ (P = 0.12) between one another (Table 55). Comparison of topographical obstruction based upon mule deer sex ratios did not differ (P = 0.19) between “yes” ($\bar{x}$ = 0.26) and “no” ($\bar{x}$ = 0.30, Table 56). Furthermore, mule deer sex ratios calculated relative to distance from cover did not differ (P = 0.05) for either the 0 to 50-meter category ($\bar{x}$ = 0.27) or the 50+ meter category ($\bar{x}$ = 0.34, Table 57). Our question of completeness of count for 2012 (P = 0.69) did not differ between “maybe” ($\bar{x}$ = 0.30), “yes” ($\bar{x}$ = 0.30) and “no” ($\bar{x}$ = 0.23, Table 58). Our question of completeness of count for 2013 also was similar (P = 0.35) between “yes” ($\bar{x}$ = 0.28) and “no” ($\bar{x}$= 0.23, Table 59) questions.

Catch Per Unit Effort (CPUE)

CPUE was calculated at the request of SDGFP and was based upon deer counted and the time it took in minutes to count those deer, this calculation was only performed in 2013 and data are presented for both deer species combined for daylights counts. Average deer counted per minute for September and October was 0.20 and 0.30, respectively, during daylight counts. Months were compared with and without the Black Hills, an area with a disproportionally high CPUE, in the data set. When the Black Hills was excluded, we found there was a difference (P = 0.04) between September ($\bar{x}$ = 0.18) and October ($\bar{x}$ = 0.30) CPUE (Table 60); if the Black hills was included there was no difference (P = 0.06, Table 61). We also calculated CPUE for spotlight counts in 2013, average deer counted per minute for September and October was 0.26 and 0.27, respectively. We found both September ($\bar{x}$ = 0.26) and October ($\bar{x}$ = 0.27) were similar (P = 0.85) for our comparison of deer counted per month (Table 62).

Discussion

Sample Size

One of our primary objectives was to determine a minimum sample size to adequately estimate age ratios of white-tailed and mule deer. We calculated sample size to ascertain age ratio stabilization (variation within 5%). We randomized our age ratios by group for all samples and calculated a ratio for samples in cumulative denominations of 10. This method of sample-based rarefaction is described by Gotelli (2011) as a realistic measure in most biodiversity studies. In all cases, for daylight or spotlight counts for mule deer and white-tailed deer, our ratios did not vary by more than 5% for sample sizes between 60 and 80 groups.

Sex and Age Ratios for White-tailed Deer

Our results indicated age or sex ratios of white-tailed deer were variable for many of our comparisons, which has been documented in previous studies for large mammals in other areas (Connolly 1981, McCullough 1982, McCullough and Hirth 1988, Garcia 1989). Traditionally, HCC’s in South Dakota occur in the fall and therefore, we conducted our study during this time of year. Dasmann and Taber (1956) stated that deer are most accurately counted and classed during times of year when family groups are present and not any one class is misrepresented. Bender and Spencer (1999) stated the breeding season, which is late fall in South Dakota, is an important time of year that adult males are intermixed with other demographic classes of the population and therefore, age and sex information can be collected from ungulate populations. Observation bias was questioned during this time of year but some bias is inherent in any composition study. For example, observability bias has been documented in populations where true sex and age class ratios were known (Dowing et al. 1977, McCullough 1982, Sage et. al. 1983, McCullough and Hirth 1988). Therefore, we believe comparisons made during our study were reasonable and comparable because our methods were consistent throughout our study.

We had hypothesized that October would be a better month for surveys in study area's east of the Missouri River regardless of time of day for two reasons; first, deer are more likely to congregate and not be as segregated due to breeding behavior and second, prevalent agricultural crops such as corn and soybeans were being harvested (USDA 2010), which reduced available cover and associated observation bias, in turn potentially increasing detection probabilities. Although we cannot conclude crop harvest was a main factor affecting our ratios, it likely contributed to increased means of both age and sex ratios.

McCullough (1990) noted that during the months of September and October, bucks and does had an inverse activity pattern; that is, bucks were more active at night and does more so during the day, which was congruent with our findings in September but not October. McCullough (1993) stated that daytime sex ratios of black-tailed deer (*Odocoileus hemionus*) varied widely during fall HCC counting periods, which was inconsistent with our results for mule deer sex ratios, as they were stable. However, we did see variation across months with regard to daytime white-tailed deer sex ratios, which was consistent with McCullough's (1993) findings.

Another factor that could affect collection of age and sex ratio data and lead to change in ratios is hunter harvest. South Dakota has two hunting seasons, youth and archery, which occur in mid-September and remain open through our sampling seasons. SDGFP reported (SDGFP 2014) 24,487 total archery tags statewide were issued and a success rate of 25% was achieved with a projected 6,052 deer harvested. SDGFP also reported (SDGFP 2014) 5,038 youth hunting tags issued with a success rate of 51% and a projected 2,565 deer harvested statewide. Consequently, these hunting seasons could have impacted sex or age ratios of deer species between months. It is also known that bucks in a hunted population have a lower observation rate than do does for both species of deer. Deer harvest may have been a contributing factor, albeit small, in the change of month-specific age or sex ratios we documented in our study. Quantifying the impacts of limited harvest on HCC's on such a wide scale would prove to be difficult and thus, a more thorough evaluation is warranted. One way to quantify the impacts of limited harvest would be to use radio-collared individuals and their rate of harvest during these seasons.

Age ratios generated from spotlight data indicated that there could be a close association between fawns and does because we noted a higher October age ratio count for white-tailed deer; similar findings were discussed by O'Gara and Yoakum (1992). We hypothesized that increased size of fawns in October could possibly lead to misclassification of fawns as does, skewing our age ratios to adults. Age ratios increased in October; if misclassification of fawns as does was significant, we would have expected that our ratios would have decreased.

Hirth (1977) observed that does were the center of fawn activity on the Welder Wildlife Refuge in South Texas and fawn activity increased from September to October but as the breeding season began, the association between does and fawns declined. Our results supported these findings as they relate to an increasing age ratio from September to October. As time progressed through our sampling season(s), temperatures tended to decline. It has been reported that activity of Cervids may be greater on cool days (Dasmann and Taber 1956, McMillan 1954, Harper 1962, McCullough 1990). Higher nocturnal activity may alleviate thermal stress, which was associated with our documented age and sex ratios during spotlight surveys and our increase in ratio counts during October.

Montgomery (1964) reported that deer tend to increase activity after sunset with bedding activity peaking 5 hours after sunset during fall months. McCullough (1993) stated that deer showed less alarm behavior during night spotlight counts, which could influence herd composition counts. Our findings were similar to both Montgomery (1964) and McCullough (1993) as we noted a significant difference in age and/or sex ratio during spotlight counts when compared to daylight counts in both months of study.

Complete Count

The question of, “do you feel the count is complete or not?” also proved to be somewhat variable for age ratios and sex ratios of mule deer and white-tailed deer. In 2012, the question had three responses: “yes”, “no” and “maybe”. After much thought and deliberation involving surveyors, we concluded that the answer “maybe” was not independent from other responses (yes or no). Our findings revealed that "no" was the least selected response for surveys conducted in either month (September or October) where data were collected to estimate sex and age ratios for white-tailed and mule deer. White-tailed deer age ratios from daylight and spotlight counts both differed between observers answering "yes, they were confident their counts were complete" and "no, they were not confident in their counts". This also was the case for white-tailed deer sex ratios from spotlight counts in 2012. Neither age nor sex ratios of mule deer differed relative to the "yes" or "no" responses in 2012. In 2013, even though we negated a possible cause of indecisiveness, our results closely mirrored 2012 responses with "no" being the least selected answer overall. The only occasion where there was an indication that the response to the question effected results was for mule deer age ratios. In this case surveyors had answered "yes" in a higher proportion; therefore, we believe they were highly confident their count was accurate. Our results may have been due to many of our observers having a high level of experience in HCC's and many of them participating during the two years in which data were collected.

We expected responses of observers to increase in confidence regarding complete count ("yes") in October, as crop harvest would be nearly completed (USDA 2010). Our results, however, did not support this hypothesis. Instead, we found that ratios were similar across years and confidence of complete counts was generally the same temporally. Results indicated that this question ultimately had no effect on differ in age or sex ratios of white-tailed or mule deer.

Habitat Type

During daylight counts, we found no difference in ratios calculated by habitat type for either white-tailed or mule deer. Spotlight counts for white-tailed deer were much different however. We found that age ratios for white-tailed deer generated for short grass provided a higher age ratio than for any other habitat type. Montgomery (1963) and McCullough (1993) both observed that deer selected open areas after sunset and remained there for the majority of the night. Our study had similar findings and suggested short grass habitats had a significantly different age ratio attributed to the high visibility and openness of this habitat type.

McCullough (1993) observed similar age or sex ratios in various habitat types. His findings contradict our findings; white-tailed deer sex ratios and age ratios had an inverse relationship in short grass, sex ratios were lower whereas age ratios were higher. McCullough (1993) stated that bucks have a higher tendency to show alarm behavior under spotlight than do does. Our sex ratios for white-tailed deer were lower in crop stubble, which could be attributed to alarm behavior. Beier (1987) hypothesized that bucks required a lower quality diet than does; therefore, it is possible bucks simply avoided low cover areas as they have no need to seek areas with a potentially higher quality food source.

We had hypothesized that prevalent crops, corn and soybeans, when harvested would provide less cover leading to higher counts and therefore, variation in our sex or age ratios. These crops are harvested in late September and early October (USDA 2010), which, if important, would result in a change in age and sex ratios over the two months. These crops would have been categorized as tall and short crop but age or sex ratios for these categories did not differ when compared to other habitat categories for day and spotlight counts. As Montgomery (1963) and McCullough (1993) stated, deer generally move to more open areas in the evening hours and use thick cover during daylight hours. This reasoning could be used to explain why we did not see a difference in these categories during spotlight or daylight counts.

Distance from Cover

Our study also attempted to quantify if distance from available cover affected age and/or sex ratios. Data were again pooled for daylight and spotlight counts. During daylight counts neither mule deer or white-tailed deer age or sex ratios differed between categories of 0-50 meters and 50 meters and greater from the observer. Spotlight count derived sex ratios for white-tailed deer also were similar between these two distance categories. In contrast, age ratios from spotlight counts did differ between the two categories. The greater than 50-meter category resulted a higher age ratio for white-tailed deer than did the less than 50-meter category. Misclassification of does as fawns or yearlings as fawns might have been responsible for this outcome, especially as distance and low light conditions were involved.

Topography

Topography also was evaluated relative to its effect on age and/or sex ratios. No significant difference was found for white-tailed deer sex or mule deer age or sex ratios. White-tailed deer age ratios did show a difference with “no” (i.e., total group was seen/topography was not a limiting factor in the count) selected the majority of the time. Much of South Dakota has a relatively low amount of topographical variation, which could explain the similarity between our samples.

Observation time

Observation time of both white-tailed and mule deer was quantified. We separated our data by the time, in minutes, it took for an observer to classify the deer or deer group. White-tailed deer and mule deer age and sex ratios during daylight counts did not differ relative to ratios based upon time spent counting. Spotlight counts for estimating age ratios of white-tailed deer also did not differ by time spent counting deer. Spotlight sex ratio counts of white-tailed deer did however, differ for both categories we evaluated. McCullough (1993) stated deer showed less alarm behavior under spotlight. However, bucks do have a tendency to be more cautious than does under these conditions, which is supported by our observations; higher sex ratios were documented with lower observational time categories.

Catch Per Unit Effort (CPUE)

CPUE was only calculated in 2013 and was calculated on the deer group and not on the age or sex ratio. Contrary to McCullough (1983), we found our spotlight counts did not differ between September to October in relation to CPUE. We did however see a difference in our daylight counts between these months with October providing a higher CPUE. We had postulated that our Black Hills deer counts were driving our CPUE numbers. Censoring the Black Hills counts from our results indicated that October provided a higher CPUE during daylight counts.

Management implications

Managers are tasked with not only choosing the best time of year to conduct HCC's based upon collecting accurate data but also what is logistically feasible so that data collection goals can be achieved with available staff. Nevertheless, sample size based age ratios would require a minimum of 60 to 80 deer groups per study area.

Our findings also indicated that surveys conducted in either September or October provided similar results when generating age ratios from daytime counts for either species of deer. Our recommendation would be to conduct surveys in October for both deer species. Conducting surveys in October would allow for similar age ratios as seen in September but would have the additional benefit of having higher, and possibly more accurate, sex ratios. Surveying in October would ensure all deer classes have an equal likelihood of being correctly classified due to the fact that bucks are more active this time of year and fawns are more likely to be located within family groups. CPUE based upon total deer also was quantified for this study and, it too, indicated that October was the better month for obtaining a higher deer count, when compared to September.

We found most surveyors were confident in their counts and they were cognizant of their vantage points at which they counted deer and these two variables did not affect sex or age ratios. Sex ratios generated within cattails, short crops, and crop stubble habitat types are likely biased and thus, would require adjustment when used to characterize deer populations; The same holds true for age ratios generated in short crops habitats. Distance as it related to daytime surveys showed no relationship to change in age or sex ratios.

Chapter 4

PRONGHORN HERD COMPOSITION COUNTS

Introduction

Pronghorn (*Antilocapra americana*) are the only member of the Antilocapridae family and are native to North America (O'Gara and Janis 2004). Lewis and Clark journals of 1804 described pronghorn occurring in vast numbers across the Dakota Territory. It was estimated that prior to 1800 over three-quarters of a million animals existed within their range (South Dakota Game Fish and Parks ([SDGFP] 2014). Today, pronghorn survive at much lower abundance and in South Dakota exist primarily in the western portion of the state. SDGFP estimated the population at 26,000 (CI = 18,000-33,000 SDGFP 2015) adults during spring. A high public demand for pronghorn exists in South Dakota with a 5-year average of 8,233 hunting license applicants and 5-year average of only 5,068 hunting licenses for firearms and archery being issued (SDGFP 2011-2015).

Herd composition counts (HCC) have shown high variability and low precision (Conolly 1981, McCullough 1982, McCullough and Hirth 1988, Garcia 1989) and the use of ratios to determine population size has been criticized (Caughley 1974, Caughley 1977, McCullough 1994). However, HCC are used to estimate population growth rates (Downing 1980) and estimates of survival (McCullough 1994). It has been argued that HCC are an important factor for population assessment (Engman 2003) and if applied properly can be of great use in herd management (Bender 2006). Conversely, it has been argued that without estimates of detection probabilities HCC are not reliable (Anderson 2001, Anderson 2003). Aerial herd counts can also be an effective method for classifying large species in open landscapes (Pojar et al. 1995, Rabe et al. 2002), but when habitats are dense, expense rises and efficacy of the survey decreases (Kaji 2005). Variability has been documented for ground counts on various ungulate species (McCullough 1993, McCullough et al 1994, Taber et al 1982). Studies have taken place reviewing herd composition counts but most have been limited in scope and geographic scale (Downing 1977, McCullough 1993, McCullough 1994, Kaji 2005).

Current SDGFP harvest information indicates primary harvest of pronghorn is directed towards adult bucks; therefore, it is important to have proper estimates of sex ratios so tag allocation can be properly executed. SDGFP currently uses harvest estimates, spring aerial counts, adult female survival rates from radio-collared individuals, and herd composition surveys to assess the pronghorn population. Fall classification surveys currently take place from 1 August to 30 September annually, but sample size requirements and time frame as related to detection of bucks, does, and fawns has been questioned; it was thought sample sizes were inadequate to properly determine either sex or age ratios. Our objectives for this study were: 1) determine minimum sample size of pronghorn for composition counts, 2) compare August and September age ratio counts of pronghorn, and 3) assess feasibility of obtaining sex ratios from survey data collected on pronghorn.

Methods

Data Collection

Surveys of pronghorn were conducted from 1 August to 14 August and 14 September to 28 September in 2012 and from 1 August to 19 August and 16 September to 27 September in 2013. In 2013, adequate sample size was not achieved so we extended the survey period in Haakon and Mellette counties to 27 August in an effort to achieve a larger sample. These time frames were chosen to maximize use of available personnel, allow sufficient time between survey periods, complete surveys prior to the firearm hunting season, coincide with breeding behavior of pronghorn, and to coincide with current SDGFP herd composition survey dates.

Surveys were defined as those conduced ½ hour before sunrise to ½ hour after sunset; thus, pronghorn counts were conducted throughout the day. One observer viewing both sides of the vehicle was used for these surveys. Binoculars and spotting scopes of varying types were used to maximize viewing of pronghorn during surveys. During surveys, all pronghorn regardless of age or sex were counted and observers were instructed to only count groups that they believed were unobstructed and in full view. If the observer concluded that a partial group of pronghorn was in view, an attempt was made to quantify the count; i.e., the observer moved to a better vantage point, if the entire group could not be viewed the count was not completed. Although weather conditions were undefined, days without major precipitation events were selected and temperature and wind speed were recorded at the beginning of surveys. A maximum vehicle speed of 32 km/hr was implemented to ensure areas were completely surveyed. When a pronghorn group was sighted, a GPS point, time, date, and classified count were recorded with a Trimble Juno (Trimble Navigation Limited, Sunnyvale California, USA) using Cybertracker data recording software (Cybertracker version 3.317, http://www.cybertracker.org/).

Data analysis

We set survey goals for personnel conducting surveys that were derived from spring aerial estimates obtained from the previous year (South Dakota Game, Fish and

Parks 2012, 2013) using a standard sample size formula (Zar 1999), the goals range from 60-80 female groups. Data were analyzed based upon the fawn to doe (age) and buck to doe (sex) ratios for pronghorn by comparing month of data collection across years, by data analysis unit (study area, See chapter 1 for specific study area information), and between months for each year. Variables were analyzed with t-tests assuming unequal variances with an alpha level of 0.05 and a Bonferroni correction method was used to maintain the experiment-wide error rate for multiple statistical tests. Each age ratio was calculated for high, medium, and low density study areas, which was derived from GFP spring aerial counts on adults (study areas were combined by estimated densities to reflect high, medium, and low).

The proportion of bucks to does was calculated using a proportions formula (adult bucks/ (adult bucks + adult does)) (P. Lukacs, Montana State University, personal communication). This equation was not used for our age ratios (fawns:adult does) because it is rare fawns are observed without does; however, bucks are generally seen in bachelor groups without does. Therefore, calculating a proportion of bucks to does or a sex ratio from just bucks would result in a zero as the output, which misrepresents bucks in our calculations.

For calculations for recommendations of sample size for both age and sex ratios, we generated cumulative ratios by adding observations until ratios stabilized. In other words, we took random samples of age or sex ratios in denominations of 20 and found where the prior ratio did not vary from current ratio by any more than +\- 5% in succession (i.e., stabilized). When ratios did not vary by more than 5% for several samples we concluded that the sample size was adequate.

Results

In 2012, we counted 2,152 pronghorn (374 bucks, 1,055 does, 723 fawn) in August and 2,200 (454 bucks, 1,106 does, 640 fawns) pronghorn in September. In August, our high density study area accounted for 56% of the counts or 1,196 animals (213 bucks, 553 does and 430 fawns), the medium density study area accounted for 30% of the counts or 635 animals (122 bucks, 295 does and 218 fawns), and the low density study area accounted for the remaining 14% of the counts or 321 animals (39 bucks, 207 does and 75 fawns). In September 2012, our high density study area had 52% of the count or 1,147 animals (251 bucks, 549 does and 347 fawns), the medium density study area represented 35% of the count or 777 animals (163 bucks, 379 does and 235 fawns), and the low density study area accounted for the remaining 13% or 276 animals (40 bucks, 178 does and 58 fawns)

In 2013, we counted 2,168 pronghorn (396 bucks, 1,091 does, 681 fawn) in August and 1,760 pronghorn (354 bucks, 935 does, and 471 fawns) in September. Our August counts in the high density study area accounted for 53% of the count or 1,158 animals (213 bucks, 554 does and 391 fawns), the medium density study area accounted for 32% of the count or 701 animals (128 bucks, 359 does and 214 fawns), and the low density study area accounted for the remaining 15% or 309 animals (55 bucks, 178 does and 76 fawns). In September 2013, the high density study area accounted for 55% or 957 pronghorn (215 bucks, 482 does and 260 fawns), the medium density unit accounted for 36% or 639 of the pronghorn (109 bucks, 343 does and 187 fawns), and the low density unit accounted for the remaining 9% or 164 animals (30 bucks, 110 does and 24 fawns).

Sample Size

Our minimum sample size for both age (Table 67) and sex (Table 68) ratios indicated that between 60 and 70 groups were needed to stabilize ratios in both the high and medium density study areas. Our low density study areas did not have sufficient samples to adequately calculate a minimum sample size in either 2012 or 2013.

Age Ratios

A Bonferroni correction method was used to maintain the experiment-wide error rate for multiple statistical tests; therefore, corrected alpha levels are presented for comparison to P values. Age ratios based upon high density study area's differed (corrected α P = 0.025) between August ($\bar{x}$ = 0.87) and September ($\bar{x}$ = 0.66, P = 0.001) in 2012 (Table 63). Age ratios in 2013 based upon the high density study area also differed (corrected α P = 0.025) between August ($\bar{x}$ = 0.78) and September ($\bar{x}$ = 0.56, P = 0.002) in 2012 (Table 63). Our medium density study area in 2012 differed (corrected α P= 0.025) from August ($\bar{x}$ = 0.93) to September ($\bar{x}$ = 0.58, P = 0.001, Table 63) but in 2013, ratios did not differ (corrected α P = 0.025) between months. Our low density study area in 2012 did not differ (corrected α P = 0.025) between months but in 2013 (corrected α P = 0.025), the ratio did differ from August ($\bar{x}$ = 0.57) to September ($\bar{x}$ = 0.24, P = 0.008, Table 63). A paired t-test was performed (α = 0.05) comparing August to September at the study area level to determine if ratios for this method differed; high density study area's did differ (P = 0.02), whereas medium (P = 0.03) and low density (P = 0.20) study areas did not differ (Table 64). Overall our tests suggest that August provides a higher age ratio, i.e. more fawns per doe, than in September.

Sex Ratios

A Bonferroni correction method was used to maintain the experiment-wide error rate for multiple statistical tests; therefore, corrected alpha levels are presented for comparison to P values. Sex ratios based upon high density study area's differed (corrected α $P = 0.025$) between August ($\bar{x}$ = 0.34) and September ($\bar{x}$ = 0.43, P = 0.013) in 2012 (Table 65). In 2013, sex ratios based upon high density study area did not differ (corrected α $P = 0.025$, Table 65). Our medium density study area's both in 2012 and 2013 did not differ for collection months (corrected α P = 0.025, Table 65). Our low density study area's in 2012 and 2013 did not differ (corrected α P = 0.025) between months (Table 65). A paired t-test was performed (α = 0.05) comparing August and September and each study area density to test if our values for this method were different; All study areas were similar (P = 0.05) between years (Table 66). Overall these results suggest similar sex ratios are achieved in either August or September.

Catch Per Unit Effort (CPUE)

CPUE was calculated at the request of SDGFP and was calculated based upon groups of pronghorn counted and the time it took in minutes to count those pronghorn; this calculation was only performed for 2013 data. Average pronghorn counted per minute for August and September was 0.02 pronghorn per minute and 0.04 pronghorn per minute, respectively. We found that CPUE in August differed (P =0.002) from September; more pronghorn were counted in September.

Discussion

Sample Size

Our sample size was initially calculated using a standard sample size formula utilizing spring population estimates pre-sampling period. This initial sample size was based upon 10% of our total estimate of does in a unit. This method was not only used in our study but is also currently used by SDGFP for fall HCC's. Our methodology was also similar to the method Czaplewski (1983) described and recommended for formulating minimum sample sizes. This method of formulating a sample size is based upon does counted in a group and not on the entire pronghorn group. Sample size based upon population estimates were used to define data collection goals for personnel during this study. We found that meeting this goal was time intensive as well as demanding on personnel, especially in low density pronghorn units.

We then sought to determine a sample size recommendation based upon age and sex ratios collected for each group observed. Bowden (1984) stated that even with the wide use of sex and age ratios in deer management, sample size requirements have received little attention. This statement also seems to hold true for pronghorn. To derive our sample size recommendation, we evaluated percent change in our age and sex ratios with each increase in sample size using our collected data. We determined that our sample size varied by less than 5 percent around 60 to 70 group samples for both sex and age ratios indicating this threshold is the point at which adequate data are obtained. Therefore, increasing our sample size higher (i.e., 80 groups,90 groups,100 groups) would not yield more precise results via a lower standard error. This method of calculating sample size is based upon the pronghorn group rather than the individual doe.

Age Ratios

We sought to compare if observed age ratios differed between August and September, which could change how herd composition surveys for pronghorn are conducted by SDGFP. Our results indicated age ratios did vary by study area. However, when comparing age ratios at the study area level, there was a statistically significant trend towards August providing higher age ratios, i.e. more fawns per doe, than September. McCullough (1993) found that black-tailed deer age ratios varied by year and by month with August having a lower ratio than September; similar variation was also reported by Garcia (1989) for Black-tailed deer and McCullough (1982) for white-tailed deer.

We hypothesized that age ratios could be skewed by misclassification of fawns as does therefore decreasing our age ratios. Our age ratios were lower in September and on more than one occasion differed significantly from August, which could be explained by misclassification. From a morphometric stand point, August would be advantageous over September for conducting surveys as there is still a discernable size difference between fawns and does. High morphological distinctions between fawns and does can lead to precise fawn: doe ratios (O'Gara and Yoakum 1992). In Northwest and west-central South Dakota, average monthly survival of neonate pronghorn was 0.96 and 0.95 in August 2015 and 2016, respectively (A. Kauth, South Dakota State University, unpublished data). Kauth also reported an average monthly survival of 0.92 and 0.93 in September 2015 and 2016, respectively. Jacques (2006) reported a monthly pronghorn neonate survival rate of 1.0 in Southwest South Dakota for August 2003-2005. Jacques (2006) also reported a 0.98 monthly survival rate of pronghorn neonates in Northwestern

South Dakota for 2002-2004. These findings further suggest that a decrease in age ratios was not solely due to neonate mortality but, likely, due to a misclassification of fawns as does in September.

Our mean age ratios ranged from a low of 0.23 fawns per does (F:D) in our low density study area in September to a high of 0.93 F:D in our medium density study area for August. Our lowest ratios were in the eastern portion of the current pronghorn range in the State of South Dakota. Conversely, our high and medium density areas were characterized by higher amounts of sagebrush (*Artemisia* spp.) steppe habitat, open grasslands, and less row-crop operations. In Oregon, Phillips and White (2003) reported ratios that ranged from 0.30 to 0.58 F:D over a 20-year time span and Whittaker et al. (2003) reported similar age ratios in a 9-year time span. In Kansas, age ratios of 0.17 to 0.42 F:D have been reported for three management units utilizing aerial surveys in 2013 and for a range of age ratios of 0.90 to 0.86 F:D over a 12-year period (Kansas Department of Wildlife Parks and Tourism 2013). Firchow (1990) reported age ratios of 0.27 to 0.33 F:D and 0.17 to 0.39 F:D in August strip and quadrat samples, respectively, in Colorado.

Sex Ratios

Quantified sex ratios of pronghorn did not support differences related to months of data collection in our high or medium density study areas. Our sample size in our low density study area was much lower than in the other study areas, although our ratios were not significantly different. Due to the lack of pronghorn on the landscape it was not possible to obtain a larger sample in these low-density study areas. We also cannot fully rule out observer bias affecting our results. We believe bias was minimized by having the same observers in the same study areas who were experienced with aging, sexing, and performing HCC for pronghorn. However, observer bias can vary with experience of the observer (LeResche and Rausch 1974, Caughley et al. 1976), and to reduce bias observers with similar experience are recommended (Samuel et al. 1987, Ackerman 1988). We would have expected a lower ratio of bucks in August due to lower detection as they may occur alone (Ingold 1969, Kitchen 1974) or occur in smaller easily missed groups (Cook and Jacobson 1979, Samuel and Pollock 1981). Our study does indicate a lower mean ratio for in August but the difference was not great enough to warrant selecting one month for sampling over another. We had also postulated that lone bucks would be difficult to observe and thus, would not be accounted for in August whereas; in September they would be more observable due to the lone bucks being in groups.

Our mean sex ratios ranged from 0.22 (*SE* = 0.03) bucks per doe (B:D) in our low density study area to 0.46 (*SE* = 0.02) B:D in our high density study area. Our study findings align with those of Woolley and Lindzey (1997) in their three Wyoming study sites, where during a similar time of year, they found an average of 0.48 B:D, 0.58 B:D, and 0.24 B:D, respectively. Pojar et al. (1995) documented 0.53 B:D in Colorado. In Nevada, a sex ratio of 0.50 B:D was documented (Maher 1991). For additional comparison spring aerial survey derived B:D ratios provided by SDGFP (unpublished data) in 2012 and 2013 ranged from 0.33 B:D to 0.43 B:D compared to our ratios of 0.34 (*SE*=0.03) to 0.46 (*SE*=0.02) in our high density units. Medium density units ranged from 0.30 B:D to 0.61 B:D during 2012 and 2013 spring aerial surveys compared to our findings of 0.34 (*SE*=0.03) to a high of 0.44 B:D (*SE*=0.02). Low density units during 2012 and 2013 SDGFP spring aerial counts ranged from 0.28 B:D to 0.58 B:D compared to our sex ratios of 0.22 B:D (*SE*=0.03) to 0.36 B:D (*SE*=0.02). We compared our results against SDGFP's aerial survey sex ratio results via a one-way ANOVA and found that the two ratios were similar (P=0.07). This suggests our ratios were consistent with ratios derived using other methods in South Dakota.

CPUE

September provided a higher CPUE than August. We had assumed this would be the case due to breeding behavior of bucks, formation of family groups, and the increased likelihood of observability in later months due to pronghorn being in larger groups. It has been documented that bucks are usually alone and less likely to be seen in August and family groups are formed during breeding season (Kitchen 1974, Wooley 1997).

Management Implications

Minimum sample size when quantifying sex or age ratios should require 60 groups in all study areas. If a minimum sample size based upon a known population estimate, as recommended by Czaplewski (1983), is used the minimum requirement for sex and/or age ratios as we recommend would, in theory, be simultaneously met. Consideration should be given when seeking minimum sample sizes in units with low pronghorn densities as it is possible, due to lack of pronghorn on the landscape, the sample size goal may not be met.

Our findings indicate that at the study area level, August should be selected over September for estimating age ratios, whereas either month is adequate for quantifying sex ratios. CPUE was higher in September. However, when determining a period to sample consideration should be given to other factors such as behavior of pronghorn and morphometric differences. Given these factors, classifying the herd in August would be the best solution to alleviate misclassification and to maximize age ratios based on a study area level. In addition, our study indicates that an adequate sex ratio also can be obtained if counts were collected in the month of August.

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Table 1. Total deer identified during pilot study on each transect for all different sampling methods.

Transect	Dawn1	Dawn2	Dusk1	Dusk2	Spot1	Spot2
BOGUS JIM	4	11	13	14	10	28
CUSTER CROSSING	3	1	1	6	13	12
KELLY SPUR	5	17	6	18	20	17
NEWTON FORK	0	3	10	5	8	19
VICTORIA CREEK	40	31	23	31	33	56

Table 2. The percentage increase of deer observed at each transect from one observer to two observers.

Transect	# Observers	Bucks	Does	Fawns	Unknown	Sum Total	% Increase
BOGUS JIM	1	5	16	5	0	27	
BOGUS JIM	2	6	19	14	14	55	**50.91%**
CUSTER CROSSING	1	0	6	3	8	18	
CUSTER CROSSING	2	1	13	4	1	21	**14.29%**
KELLY SPUR	1	3	17	4	7	32	
KELLY SPUR	2	9	24	12	7	54	**40.74%**
NEWTON FORK	1	1	8	4	5	19	
NEWTON FORK	2	2	16	6	3	29	**34.48%**
VICTORIA CREEK	1	9	38	17	32	97	
VICTORIA CREEK	2	12	60	22	24	120	**19.17%**

Table 3. The percentage of unknowns in total deer observed with one observer and two observers.

Observers	Bucks	Does	Fawns	Total Known	Total Unknown	% Unknown
1	18	85	33	136	52	38.24%
2	30	132	58	220	49	22.27%

Table 4. Distance Outputs for 2012-2014. DS=Density of Clusters (How many deer in each group), D=Density of Animals (deer/Kilometer squared), N=Population estimate, SE=Standard Error.

Year	Variable	Parameter	Estimate	SE	95% Confidence Interval	
2012	Meadow	Density of Clusters (DS)	6.8	1.55	4.29	10.77
		Density of Animals (D)	14.21	3.38	8.84	22.85
		N	22930	5450	14260	36871
2012	Tree	Density of Clusters (DS)	3.66	0.8	2.41	5.57
		Density of Animals (D)	7.88	1.74	5.11	12.16
		N	31277	6926.0	20249	48155
2013	Meadow	Density of Clusters (DS)	5.47	0.95	3.85	7.76
		Density of Animals (D)	11.6	2.1	8.07	16.69
		N	18720	3390.7	13016	26925
2013	Tree	Density of Clusters (DS)	3.04	0.64	2.01	4.59
		Density of Animals (D)	4.76	1.02	3.12	7.25
		N	18838	4042.7	12361	28709
2014	Meadow	Density of Clusters (DS)	6.64	1.49	4.27	10.34
		Density of Animals (D)	13.79	3.19	8.75	21.75
		N	23050	5327.3	14618	36344
2014	Tree	Density of Clusters (DS)	3.14	0.52	2.25	4.38

		Density of Animals (D)	5.27	0.91	3.74	7.42
		N	20850	3584.3	14799	29375
2014	Meadow plus extra routes	Density of Clusters (DS)	6.86	1.33	4.68	10.05
		Density of Animals (D)	13.89	2.78	9.36	20.6
		N	23208	4648.9	15648	34419
2014	Tree plus extra routes	Density of Clusters (DS)	3.01	0.42	2.27	3.98
		Density of Animals (D)	4.71	0.68	3.54	6.28
		N	18670	2695.7	14018	24864
2012	Meadow Unit 1	Density of Clusters (DS)	2.23	0.67	1.09	4.56
		Density of Animals (D)	4.98	1.94	2.17	11.38
		N	1206	469.4	527	2760
2012	Tree Unit 1	Density of Clusters (DS)	0.88	0.47	0.26	3.03
		Density of Animals (D)	2.29	1.37	0.65	8.11
		N	1278	764.47	361	4523
2012	Meadow Unit 2	Density of Clusters (DS)	4.47	1.34	2.37	8.42
		Density of Animals (D)	8.03	2.51	4.2	15.36
		N	4387	1370	2294	8389
2012	Tree Unit 2	Density of Clusters (DS)	3.29	0.58	2.31	4.68

		Density of Animals (D)	7.1	1.36	4.84	10.39
		N	12307	2366.9	8403	18025
2012	Meadow Unit 3	Density of Clusters (DS)	14.16	12.52	0.01	33543
		Density of Animals (D)	38.75	35.3	0.07	21151
		N	9385	8551.1	17	5123100
2012	Tree Unit 3	Density of Clusters (DS)	3.15	1.42	1.14	8.72
		Density of Animals (D)	4.59	2.12	1.65	12.76
		N	3483	1607.8	1254	9676
2012	Meadow Unit 4	Density of Clusters (DS)	10.34	3.94	4.45	24
		Density of Animals (D)	21.16	8.45	8.99	49.81
		N	12330	4926.1	5238	29024
2012	Tree Unit 4	Density of Clusters (DS)	4.64	1.57	2.29	9.44
		Density of Animals (D)	11.28	4.1	5.38	23.68
		N	10252	3724.4	4886	21508
2013	Meadow Unit 1	Density of Clusters (DS)	2.92	1.72	0.07	121.34
		Density of Animals (D)	6.02	3.78	0.37	98.81
		N	1460	916.69	89	23960
2013	Tree Unit 1	Density of Clusters (DS)	2.48	2.11	0.04	172.66

		Density of Animals (D)	3.58	3.1	0.01	178.19
		N	1997	1729	40	99331
2013	Meadow Unit 2	Density of Clusters (DS)	5.61	1.21	3.6	8.75
		Density of Animals (D)	12.15	2.74	7.67	19.25
		N	6639	1497.9	4192	10515
2013	Tree Unit 2	Density of Clusters (DS)	2.88	0.63	1.84	4.51
		Density of Animals (D)	4.44	1.02	2.79	7.05
		N	7695	1766.6	4840	12236
2013	Meadow Unit 3	Density of Clusters (DS)	19.4	4.57	10.74	35.06
		Density of Animals (D)	46.35	12.93	25.14	85.46
		N	11227	3130.7	6089	20700
2013	Tree Unit 3	Density of Clusters (DS)	3.15	1.42	1.14	8.72
		Density of Animals (D)	4.59	2.12	1.65	12.76
		N	3483	1607.8	1254	9676
2013	Meadow Unit 4	Density of Clusters (DS)	3.21	1.31	1.27	8.13
		Density of Animals (D)	7.38	3.2	2.88	18.94
		N	4302	1862.6	1677	11037
2013	Tree Unit 4	Density of Clusters (DS)	4.66	1.66	2.03	10.72

		Density of Animals (D)	8.09	3	3.5	18.68
		N	7351	2727.2	3184	16969
2014	Meadow Unit 1	Density of Clusters (DS)	4.62	1.51	2.17	9.81
		Density of Animals (D)	6.35	2.24	2.93	13.74
		N	1539	543.58	711	3332
2014	Tree Unit 1	Density of Clusters (DS)	1.32	0.74	0.27	6.42
		Density of Animals (D)	2.28	1.37	0.51	10.26
		N	1273	764.02	284	5719
2014	Meadow Unit 2	Density of Clusters (DS)	6.26	1.4	3.91	10
		Density of Animals (D)	12.8	3.01	7.88	20.79
		N	6994	1646.1	4306	11358
2014	Tree Unit 2	Density of Clusters (DS)	3.07	0.56	2.13	4.44
		Density of Animals (D)	5.1	0.97	3.47	7.48
		N	8842	1686	6025	12975
2014	Meadow Unit 3	Density of Clusters (DS)	9.75	4.41	2.76	34.4
		Density of Animals (D)	24.89	12.74	7.51	82.43
		N	6027	3085.7	1820	19962
2014	Tree Unit 3	Density of Clusters (DS)	3.28	1.72	0.97	11.05

		Density of Animals (D)	4.79	2.57	1.42	16.11
		N	3631	1945.7	1079	12218
2014	Meadow Unit 4	Density of Clusters (DS)	10.11	5.57	2.26	45.3
		Density of Animals (D)	21.56	12.34	5.02	92.57
		N	12562	7190	2926	53937
2014	Tree Unit 4	Density of Clusters (DS)	4.57	2.1	1.57	13.35
		Density of Animals (D)	9.01	4.23	3.09	26.29
		N	8184	3843.5	2805	23881
2014	Meadow Unit 1 + Extra Routes	Density of Clusters (DS)	4.62	1.51	2.17	9.81
		Density of Animals (D)	6.35	2.24	2.93	13.74
		N	1539	543.58	711	3332
2014	Tree Unit 1+ Extra Routes	Density of Clusters (DS)	3.22	1.1	1.62	6.41
		Density of Animals (D)	4.2	1.49	2.07	8.53
		N	2340	832.56	1152	4755
2014	Meadow Unit 2 + Extra Routes	Density of Clusters (DS)	6.66	1.28	4.49	9.87
		Density of Animals (D)	13.35	2.69	8.88	20.09
		N	7294	1471.4	4848	10973
2014	Tree Unit 2 + Extra Routes	Density of Clusters (DS)	2.79	0.64	1.78	4.37

		Density of Animals (D)	4.68	1.1	2.95	7.41
		N	8111	1908.1	5119	12853
2014	Meadow Unit 3 + Extra Routes	Density of Clusters (DS)	9.75	4.41	2.76	34.4
		Density of Animals (D)	24.89	12.74	7.51	82.43
		N	6027	3085.7	1820	19962
2014	Tree Unit 3 + Extra Routes	Density of Clusters (DS)	5.07	36.19	2.22	11.57
		Density of Animals (D)	8.5	36.98	3.71	19.46
		N	7726	36.98	3376	17681
2014	Meadow Unit 4 + Extra Routes	Density of Clusters (DS)	8.83	3.55	3.35	23.29
		Density of Animals (D)	16.97	7.13	6.44	44.68
		N	9886	4155	3754	26031
2014	Tree Unit 4 + Extra Routes	Density of Clusters (DS)	5.08	1.84	2.23	11.58
		Density of Animals (D)	8.5	3.15	3.72	19.46
		N	7726	2857.2	3376	17681

Table 5. Sample size calculations for each year for age ratios.

	2012Sept D:F Avg	
20	0.6575	-0.165399
40	0.76625	0.036433
60	0.738333	-0.076427
70	0.794762	0.034751
80	0.767143	0.0000690
90	0.76709	-0.030363
100	0.790381	0.002728
110	0.788225	0.012851
120	0.778095	-0.026971
130	0.799082	0.019341
140	0.783626	1

	2012 Oct D:F Avg	
20	0.682262	-0.1443
40	0.780714	0.082768
60	0.716096	-0.04999
70	0.751892	0.051673
80	0.713039	-0.02706
90	0.732331	0.013496
100	0.722447	-0.0538
110	0.761316	-0.00059
120	0.761762	0.013305
130	0.751626	-0.00494
140	0.755336	1

	2013Sept D:F Avg	
20	0.955	0.146597
40	0.815	-0.014315
60	0.826667	-0.012673
70	0.837143	0.060296
80	0.786667	0.026365
90	0.765926	0.015135
100	0.754333	-0.011529
110	0.76303	-0.02042
120	0.778611	-0.03528
130	0.806081	-0.006107
140	0.811003	1

	2013 Oct D:F Avg	
20	0.83875	0.16809
40	0.697764	0.015787
60	0.686749	-0.01981
70	0.700352	0.010639
80	0.692901	-0.00641
90	0.697344	-0.01458
100	0.707508	-0.02876
110	0.727853	-0.04036
120	0.757231	0.027611
130	0.736323	0.031592
140	0.713061	1

Table 6. ANOVA comparison of white-tailed deer age ratios between months for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sept D:F	1852	1374.303	0.742064	0.461037

Oct D:F	1811	1404.671	0.775633	0.445448		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.031782	1	1.031782	2.276007	0.131476	3.844
Within Groups	1659.64	3661	0.45333			
Total	1660.672	3662				

Table 7. ANOVA comparison of white-tailed deer age ratios by habitat type for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Cattails	79	61.73333	0.781435	0.566631
Crop Stubble	787	611.9552	0.77758	0.467829
Other	42	30.58333	0.728175	0.458015
Short Crop	441	339.1775	0.76911	0.450888
Short Grass	1157	883.8634	0.763927	0.455494
Tall Crop	172	117.4589	0.682901	0.460892
Tall Grass	524	402.4515	0.768037	0.425628
Trees	374	275.85	0.737567	0.420815
Wooded Riparian	86	53.9	0.626744	0.493904

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.137767	8	0.392221	0.865211	0.5452	1.940938
Within Groups	1655.993	3653	0.453324			
Total	1659.131	3661				

Table 8. ANOVA comparison of white-tailed deer age ratios for deer distance from cover for daylight counts**.**

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
D:F 0-50	3295	2509.618	0.761644	0.456123
D:F 50+	368	269.3555	0.731944	0.430273

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.291997	1	0.291997	0.64383	0.422379	3.844
Within Groups	1660.38	3661	0.453532			
Total	1660.672	3662				

Table 9. ANOVA comparison of white-tailed deer age ratios for observation time of 0-1 minute and 1 minute and above for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
0-1 min	1093	824.831	0.754649	0.509292
1+ min	2570	1954.142	0.760367	0.429934

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.025073	1	0.025073	0.055275	0.81414	3.844
Within Groups	1660.647	3661	0.453605			
Total	1660.672	3662				

Table 10. ANOVA comparison of white-tailed deer age ratios for observation time of 0-3 minute and 3 minute and above for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
0-3 mins	3221	2435.465	0.756121	0.45753
3+ mins	442	343.5083	0.777168	0.424608

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.172174	1	0.172174	0.379602	0.537855	3.844
Within Groups	1660.5	3661	0.453565			
Total	1660.672	3662				

Table 11. ANOVA comparison of white-tailed deer age ratios for topographical obstruction for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
D:F Topo Yes	578	368.3398	0.637266	0.413247
D:F Topo No	3085	2410.633	0.781405	0.457884

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.11361	1	10.11361	22.43237	2.26E-06	3.844
Within Groups	1650.558	3661	0.450849			
Total	1660.672	3662				

Table 12. ANOVA comparison of white-tailed deer age ratios for 2012 completeness of count for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*		
D:F Maybe	739	524.2711	0.709433	0.407957		
D:F Yes	1150	957.7047	0.832787	0.434722		
D:F No	83	51.11861	0.615887	0.49906		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9.106817	2	4.553409	10.65449	2.5E-05	3.000295
Within Groups	841.4911	1969	0.42737			
Total	850.598	1971				

Table 13. ANOVA comparison of white-tailed deer age ratios for 2013 completeness of count for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*		
D:F Yes	1306	1058.126	0.810203	0.491912		
D:F No	385	187.753	0.48767	0.353363		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	30.93209	1	30.93209	67.18342	4.84E-16	3.84697
Within Groups	777.6368	1689	0.460413			
Total	808.5689	1690				

Table 14. ANOVA comparison of white-tailed deer age ratios for topographical obstruction for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*		
No	2044	1443.797	0.706359	0.534683		
Yes	217	150.594	0.693982	0.505773		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.030052	1	0.030052	0.056497	0.812142	3.845579
Within Groups	1201.604	2259	0.531919			
Total	1201.634	2260				

Table 15. ANOVA comparison of white-tailed deer age ratios for deer distance from cover for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*		
F:D 0-50	1973	1363.913	0.691289	0.529305		
50+	288	230.4784	0.800272	0.539578		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.984959	1	2.984959	5.625517	0.017784	3.845579
Within Groups	1198.649	2259	0.530611			
Total	1201.634	2260				

Table 16. ANOVA comparison of white-tailed deer age ratios for observation time of 0-1 minute and 1 minute and above for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
F:D 0-1	488	351.7	0.720697	0.55804
1+	1773	1242.691	0.700898	0.524672

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.15001	1	0.15001	0.282044	0.595417	3.845579
Within Groups	1201.484	2259	0.531866			
Total	1201.634	2260				

Table 17. ANOVA comparison of white-tailed deer age ratios for observation time of 0-3 minute and 3 minute and above for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
F:D 0-3	1843	1291.233	0.700615	0.532782
3+	418	303.1582	0.725259	0.52768

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.206927	1	0.206927	0.389076	0.532848	3.845579
Within Groups	1201.427	2259	0.53184			
Total	1201.634	2260				

Table 18. ANOVA comparison of white-tailed deer age ratios for 2012 completeness of count for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
no	31	18.59167	0.599731	0.946261
yes	709	551.6167	0.778021	0.519404
maybe	344	186.1357	0.541092	0.447997

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.30853	2	6.654265	13.08367	2.43E-06	3.00405
Within Groups	549.7893	1081	0.508593			
Total	563.0978	1083				

Table 19. ANOVA comparison of white-tailed deer age ratios for 2013 completeness of count for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
no	208	89.1	0.428365	0.429339
yes	969	748.9474	0.772908	0.546715

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20.32804	1	20.32804	38.64375	7.05E-10	3.849385
Within Groups	618.0933	1175	0.526037			
Total	638.4213	1176				

Table 20. ANOVA comparison of white-tailed deer age ratios between months for spotlight counts**.**

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sept F:D	1155	652.0308	0.564529	0.468985
Oct F:D	1106	942.3607	0.852044	0.555404

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	46.70445	1	46.70445	91.35218	3.01E-21	3.845579
Within Groups	1154.93	2259	0.511257			
Total	1201.634	2260				

Table 21. ANOVA comparison of white-tailed deer age ratios by habitat type for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Cattails	133	80.76667	0.607268	0.45839
Crop Stubble	609	444.894	0.730532	0.490182
Other	18	6.5	0.361111	0.347222
Short Crop	357	234.2333	0.656116	0.522783
Tall Crop	85	49	0.576471	0.669678
Tall Grass	373	235.6024	0.631642	0.521933
Trees	145	92.6	0.638621	0.416581
Wooded Riparian	16	9.5	0.59375	0.473958
Short Grass	525	441.2951	0.840562	0.601198

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.54541	8	2.318176	4.412629	2.59E-05	1.942509
Within Groups	1183.089	2252	0.52535			

Total	1201.634	2260

Table 22. ANOVA comparison of white-tailed deer age ratios between spotlight and daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
D:F Daylight	1586	1226.897	0.77358	0.513901
D:F Spotlight	2261	1594.391	0.705171	0.531697

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.362202	1	4.362202	8.319085	0.003945	3.843878
Within Groups	2016.167	3845	0.524361			
Total	2020.53	3846				

Table 23. ANOVA comparison of white-tailed deer age ratios for September comparing daylight and spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sept Day DF	721	554.318	0.768818	0.530892
Sept Spot D:F	1155	652.0308	0.564529	0.468985

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.52577	1	18.52577	37.59521	1.06E-09	3.846426
Within Groups	923.45	1874	0.492769			
Total	941.9758	1875				

Table 24. ANOVA comparison of white-tailed deer age ratios for October comparing daylight and spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Day light Oct D:F	865	672.5795	0.777549	0.500302
Spotlight Oct D:F	1106	942.3607	0.852044	0.555404

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.693669	1	2.693669	5.07067	0.024444	3.846186
Within Groups	1045.983	1969	0.531225			
Total	1048.677	1970				

Table 25. ANOVA comparison of mule deer age ratios between months for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sept D:F	380	235.7988	0.620523	0.405658
Oct D:F	331	218.9627	0.661519	0.320808

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.297316	1	0.297316	0.811973	0.367844	3.854608
Within Groups	259.6108	709	0.366165			
Total	259.9081	710				

Table 26. ANOVA comparison of mule deer age ratios by habitat type for daylight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Cattails	1	1	1	#DIV/0!
Crop Stubble	113	61.20023	0.541595	0.296893
Other	9	4.7	0.522222	0.479444
Short Crop	73	50.04469	0.685544	0.388114
Short Grass	353	231.4579	0.655688	0.358143
Tall Crop	26	17.29206	0.665079	0.422608
Tall Grass	96	64.48333	0.671701	0.446827
Trees	15	8.9	0.593333	0.43781
Wooded Riparian	25	15.68333	0.627333	0.330437

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.736384	8	0.217048	0.59018	0.78645	1.951576
Within Groups	258.1717	702	0.367766			
Total	259.9081	710				

Table 27. ANOVA comparison of mule deer age ratios for observation time of 0-1 minute and 1 minute and above for daylight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
D:F 0-1 min	182	129.1607	0.709674	0.49346

D:F 1+ min	528	325.6008	0.616668	0.320705		

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.170763	1	1.170763	3.208716	0.073674	3.854627
Within Groups	258.3276	708	0.36487			
Total	259.4984	709				

Table 28. ANOVA comparison of mule deer age ratios for observation time of 0-3 minute and 3 minute and above for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
D:F 0-3 min	581	375.9507	0.647075	0.39847
D:F 3+ min	129	78.81085	0.610937	0.220688

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.137862	1	0.137862	0.376335	0.539768	3.854627
Within Groups	259.3605	708	0.366328			
Total	259.4984	709				

Table 29. ANOVA comparison of mule deer age ratios for topographical obstruction for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
D:F NO	521	336.9125	0.646665	0.400583
D:F Yes	190	117.8491	0.620258	0.272528

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.097086	1	0.097086	0.264938	0.606908	3.854608
Within Groups	259.811	709	0.366447			

Total	259.9081	710

Table 30. ANOVA comparison of mule deer age ratios for deer distance from cover for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
0-50	600	381.545	0.635908	0.362267
50+	110	73.21658	0.665605	0.389163

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.08198	1	0.08198	0.22374	0.63635	3.854627
Within Groups	259.4164	708	0.366407			
Total	259.4984	709				

Table 31. ANOVA comparison of mule deer age ratios for 2012 completeness of count for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
No	19	12.44444	0.654971	0.505686
Yes	293	185.0634	0.631616	0.335372
Maybe	106	58.08199	0.547943	0.309462

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.582645	2	0.291323	0.866506	0.421177	3.017462
Within Groups	139.5246	415	0.336204			
Total	140.1073	417				

Table 32. ANOVA comparison of mule deer age ratios for 2013 completeness of count for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
No	49	23.98333	0.489456	0.258703
Yes	244	175.1884	0.717985	0.429828

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.131094	1	2.131094	5.306493	0.021951	3.873613
Within Groups	116.866	291	0.401601			
Total	118.9971	292				

Table 33. ANOVA comparison of white-tailed deer sex ratios between months for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sept B:D	2101	374.5609	0.178277	0.117872
Oct B :D	2111	450.4716	0.213393	0.130787

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.298416	1	1.298416	10.44207	0.001241	3.843669
Within Groups	523.4914	4210	0.124345			
Total	524.7898	4211				

Table 34. ANOVA comparison of white-tailed deer sex ratios by habitat type for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Cattails	92	15.17857	0.164984	0.126285

Crop Stubble	615	140.2129	0.227988	0.1443		
Other	47	8.412698	0.178994	0.121589		
Short Crop	499	88.93486	0.178226	0.116918		
Short Grass	605	128.3224	0.212103	0.128104		
Tall Crop	203	40.09768	0.197526	0.136266		
Tall Grass	597	117.9702	0.197605	0.122389		
Trees	438	85.41071	0.195002	0.130212		
Wooded Riparian	102	23.57738	0.231151	0.140477		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.032404	8	0.129051	0.996843	0.436183	1.941305
Within Groups	412.8457	3189	0.129459			
Total	413.8781	3197				

Table 35. ANOVA comparison of white-tailed deer sex ratios for observation time of 0-1 minute and 1 minute and above for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*		
0-1 mins	1310	271.1998	0.207023	0.14511		
1+ mins	2902	553.8327	0.190845	0.115341		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.236215	1	0.236215	1.895833	0.168619	3.843669
Within Groups	524.5536	4210	0.124597			
Total	524.7898	4211				

Table 36. ANOVA comparison of white-tailed deer sex ratios for observation time of 0-3 minute and 3 minute and above for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
0-3 mins	3732	727.9734	0.195063	0.128013
3+ mins	480	97.05911	0.202206	0.098436

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.021706	1	0.021706	0.174135	0.676484	3.843669
Within Groups	524.7681	4210	0.124648			
Total	524.7898	4211				

Table 37. ANOVA comparison of white-tailed deer sex ratios for topographical obstruction for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B:D Topo Yes	660	142.5648	0.216007	0.12341
B:D Topo No	3552	682.4677	0.192136	0.124794

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.317156	1	0.317156	2.545849	0.110659	3.843669
Within Groups	524.4726	4210	0.124578			
Total	524.7898	4211				

Table 38. ANOVA comparison of white-tailed deer sex ratios distance from cover for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B:D 0-50	3784	734.533	0.194115	0.124174
B:D 50+	428	90.49945	0.211447	0.128625

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.115503	1	0.115503	0.926801	0.335751	3.843669
Within Groups	524.6743	4210	0.124626			
Total	524.7898	4211				

Table 39. ANOVA comparison of white-tailed deer sex ratios for 2012 completeness of count for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B:D Maybe	838	158.1405	0.188712	0.117891
B:D Yes	1340	285.2763	0.212893	0.13254
B:D No	90	18.78258	0.208695	0.105005

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.303717	2	0.151858	1.204797	0.299945	2.999698
Within Groups	285.4915	2265	0.126045			
Total	285.7953	2267				

Table 40. ANOVA comparison of white-tailed deer sex ratios for 2013 completeness of count for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B:D No	433	71.6428	0.165457	0.109541
B:D Yes	1511	291.1903	0.192714	0.126566

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.250039	1	0.250039	2.036495	0.153724	3.846252
Within Groups	238.4367	1942	0.122779			
Total	238.6867	1943				

Table 41. ANOVA comparison of white-tailed deer sex ratios for topographical obstruction for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
No	2626	693.9375	0.264256	0.172963
Yes	264	63.85873	0.241889	0.152638

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.120013	1	0.120013	0.701373	0.402392	3.844681
Within Groups	494.1714	2888	0.171112			
Total	494.2914	2889				

Table 42. ANOVA comparison of white-tailed deer sex ratios for deer distance from cover for spotlight counts

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B:D 0-50	2528	667.546	0.264061	0.172261
50+	362	90.25024	0.24931	0.163212

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.068901	1	0.068901	0.402622	0.525788	3.844681
Within Groups	494.2225	2888	0.17113			
Total	494.2914	2889				

Table 43. ANOVA comparison of white-tailed deer sex ratios by habitat type for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Cattails	161	33.45	0.207764	0.147136
Crop Stubble	754	181.3016	0.240453	0.157978
Other	26	9.333333	0.358974	0.210427
Short Crop	485	150.7385	0.310801	0.193274
Tall Crop	127	44.03333	0.346719	0.219758
Tall Grass	490	141.6333	0.289048	0.181303
Trees	211	74.8	0.354502	0.20705
Wooded Riparian	23	7.5	0.326087	0.218379
Short Grass	613	115.0062	0.187612	0.130016

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.785061	8	1.098133	6.516331	1.91E-08	1.941615
Within Groups	485.5064	2881	0.16852			

Total	494.2914	2889

Table 44. ANOVA comparison of white-tailed deer sex ratios for observation time of 0-1 minute and 1 minute and above for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
F:D 0-1	734	263.6	0.359128	0.219009
1+	2156	494.1962	0.229219	0.150588

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9.241142	1	9.241142	55.02196	1.56E-13	3.844681
Within Groups	485.0503	2888	0.167954			
Total	494.2914	2889				

Table 45. ANOVA comparison of white-tailed deer sex ratios for observation time of 0-3 minute and 3 minute and above for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B:D 0-3	2423	669.4857	0.276304	0.181854
3+	467	88.31053	0.189102	0.10915

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.977366	1	2.977366	17.5013	2.96E-05	3.844681
Within Groups	491.3141	2888	0.170123			
Total	494.2914	2889				

Table 46. ANOVA comparison of white-tailed deer sex ratios for 2012 completeness of count for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
12 B:D NO	34	4.813492	0.141573	0.08931
B:D Yes	913	253.9381	0.278136	0.174254
B:D Maybe	407	83.26905	0.204592	0.13946

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.952498	2	0.976249	6.036551	0.002455	3.002385
Within Groups	218.4878	1351	0.161723			
Total	220.4403	1353				

Table 47. ANOVA comparison of white-tailed deer sex ratios for 2013 completeness of count for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
13 B:D no	249	47.75	0.191767	0.140072
B:D yes	1287	368.0256	0.285956	0.184313

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.85092 2	1	1.850922	10.44769	0.001254	3.847528
Within Groups	271.764 8	1534	0.177161			
Total	273.615 8	1535				

Table 48. ANOVA comparison of white-tailed deer sex ratios between months for spotlight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sept B:D	1460	357.7062	0.245004	0.168198
Oct B:D	1430	400.09	0.279783	0.17356

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.873827	1	0.873827	5.114557	0.0238	3.844681
Within Groups	493.4176	2888	0.170851			
Total	494.2914	2889				

Table 49. ANOVA comparison of white-tailed deer sex ratios between spotlight and daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B:D Daylight	1835	327.9581	0.178724	0.125006
B:D Spotlight	2890	757.7962	0.262213	0.171094

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.823399	1	7.823399	51.06733	1.03E-12	3.843428
Within Groups	723.5528	4723	0.153198			
Total	731.3762	4724				

Table 50. ANOVA comparison of white-tailed deer sex ratios for September comparing daylight and spotlight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance		
Sept Day B:D	797	101.3768	0.127198	0.09651		
Sept Spot B:D	1460	357.7062	0.245004	0.168198		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.155111	1	7.155111	50.07339	1.97E-12	3.845586
Within Groups	322.2225	2255	0.142892			
Total	329.3777	2256				

Table 51. ANOVA comparison of white-tailed deer sex ratios for October comparing daylight and spotlight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance		
Daylight Oct B:D	1038	226.5813	0.218286	0.143393		
Spotlight Oct B:D	1430	400.09	0.279783	0.17356		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.274539	1	2.274539	14.13862	0.000174	3.845233
Within Groups	396.7158	2466	0.160874			
Total	398.9903	2467				

Table 52. ANOVA comparison of mule deer sex ratios between months for daylight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Sept B:D	466	124.6451	0.267479	0.154925
Oct B:D	406	129.2615	0.318378	0.143026

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.562108	1	0.562108	3.762797	0.052728	3.85217
Within Groups	129.9656	870	0.149386			
Total	130.5277	871				

Table 53. ANOVA comparison of mule deer sex ratios by habitat type for daylight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Cattails	1	0	0	#DIV/0!
Crop Stubble	132	34.40794	0.260666	0.13008
Other	11	2.7	0.245455	0.162727
Short Crop	92	29.30542	0.318537	0.157921
Short Grass	437	132.6079	0.303451	0.15279
Tall Crop	36	12.54167	0.34838	0.193666
Tall Grass	115	29.16746	0.25363	0.146826
Trees	19	4.666667	0.245614	0.17089
Wooded Riparian	29	8.509524	0.293432	0.12841

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.684872	8	0.085609	0.569	0.803825	1.949115
Within Groups	129.8428	863	0.150455			
Total	130.5277	871				

Table 54. ANOVA comparison of mule deer sex ratios for observation time of 0-1 minute and 1 minute and above for daylight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
B:D 0-1	246	79.50079	0.323174	0.188382
B:D 1+	626	174.4058	0.278604	0.134437

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.350822	1	0.350822	2.344618	0.12608	3.85217
Within Groups	130.1769	870	0.149629			
Total	130.5277	871				

Table 55. ANOVA comparison of mule deer sex ratios for observation time of 0-3 minute and 3 minute and above for daylight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
B:D 0-3	730	218.8387	0.299779	0.160349
B:D 3+	142	35.06791	0.246957	0.094336

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.331683	1	0.331683	2.216383	0.136915	3.85217
Within Groups	130.196	870	0.149651			
Total	130.5277	871				

Table 56. ANOVA comparison of mule deer sex ratios for topographical obstruction for daylight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
B:D No	651	195.974	0.301035	0.157678
D:F yes	221	57.93262	0.262139	0.126307

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.249622	1	0.249622	1.666983	0.197006	3.85217
Within Groups	130.2781	870	0.149745			
Total	130.5277	871				

Table 57. ANOVA comparison of mule deer sex ratios for deer distance from cover for daylight counts.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
0-50	728	203.6779	0.279777	0.145308
50+	144	50.22874	0.348811	0.170043

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.572923	1	0.572923	3.835512	0.050497	3.85217
Within Groups	129.9548	870	0.149373			
Total	130.5277	871				

Table 58. ANOVA comparison of mule deer sex ratios for 2012 completeness of count for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*		
No	23	5.381818	0.233992	0.144943		
Yes	367	111.5468	0.303942	0.156086		
Maybe	130	40.00001	0.307692	0.148972		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.11195	2	0.055975	0.363859	0.695167	3.013158
Within Groups	79.53372	517	0.153837			
Total	79.64567	519				

Table 59. ANOVA comparison of mule deer sex ratios for 2013 completeness of count for daylight counts.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*		
No	57	13.24683	0.2324	0.130518		
Yes	295	83.73112	0.283834	0.147285		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.126373	1	0.126373	0.873934	0.350513	3.868165
Within Groups	50.61069	350	0.144602			
Total	50.73706	351				

Table 60. T-test comparing deer groups counted per minute of time spent during daylight counts for the entire state.

Statewide CPUE w/BH

	Variable 1	Variable 2
Mean	0.203459	0.309447
Variance	0.158913	0.684602
Observations	252	253
Pooled Variance	0.42228	
Hypothesized Mean Difference	0	
df	503	
t Stat	-1.83261	
P(T<=t) one-tail	0.033726	
t Critical one-tail	1.647889	
P(T<=t) two-tail	0.067451	
t Critical two-tail	1.964691	

Table 61. T-test comparing deer groups counted per minute of time spent during daylight counts for the entire state excluding the Black Hills.

Statewide CPUE w/ No BH
t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.184909	0.308684
Variance	0.104831	0.729384
Observations	229	236
Pooled Variance	0.421829	
Hypothesized Mean Difference	0	
df	463	
t Stat	-2.05452	
P(T<=t) one-tail	0.020243	
t Critical one-tail	1.648151	
P(T<=t) two-tail	0.040486	
t Critical two-tail	1.965101	

Table 62. T-test comparing deer groups counted per minute of time spent during spotlight counts for the entire state.

Statewide CPUE spotlight
t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	0.265102	0.277339
Variance	0.443141	0.022301
Observations	109	66
Hypothesized Mean Difference	0	
df	125	
t Stat	-0.1844	
P(T<=t) one-tail	0.427	
t Critical one-tail	1.657135	
P(T<=t) two-tail	0.853999	
t Critical two-tail	1.979124	

Table 63. Pronghorn age ratios by study area. F:D=fawn to doe ratio. High=high density study area, Medium=medium density study area, Low=low density study area. For a full description of each study area and unit please see chapter 1.

Comparisons	Ratio	Year	study area Density	Aug	Sept	P=value	Adjusted Alpha
Aug Vs Sept	F:D	2012	High	0.871	0.662	0.001	0.025
Aug Vs Sept	F:D	2013	High	0.789	0.563	0.002	0.025
Aug Vs Sept	F:D	2012	Medium	0.931	0.575	0.001	0.025
Aug Vs Sept	F:D	2013	Medium	0.684	0.571	0.280	0.025
Aug Vs Sept	F:D	2012	Low	0.477	0.304	0.067	0.025
Aug Vs Sept	F:D	2013	Low	0.572	0.238	0.008	0.025

Table 64. Pooled pronghorn age ratios by study area density. F:D=fawn to doe ratio. High=high density study area, Medium=medium density study area, Low=low density study area. For a full description of each study area and unit please see chapter 1.

Comparisons	Ratio	Year	study area Density	Aug	Sept	P=value
Aug Vs Sept	F:D	Both	High	0.829	0.612	0.024
Aug Vs Sept	F:D	Both	Medium	0.807	0.573	0.304

Aug Vs Sept	F:D	Both	Low	0.524		0.271	0.196

Table 65. Pronghorn sex ratios by study area. B:D=buck to doe ratio. High=high density study area, Medium=medium density study area, Low=low density study area. For a full description of each study area and unit please see chapter 1.

Comparisons	Ratio	Year	study area Density	Aug	Sept	P=value	Adjusted Alpha
Aug Vs Sept	B:D	2012	High	0.347	0.435	0.013	0.025
Aug Vs Sept	B:D	2013	High	0.402	0.469	0.086	0.025
Aug Vs Sept	B:D	2012	Medium	0.349	0.445	0.056	0.025
Aug Vs Sept	B:D	2013	Medium	0.396	0.422	0.619	0.025
Aug Vs Sept	B:D	2012	Low	0.225	0.309	0.243	0.025
Aug Vs Sept	B:D	2013	Low	0.314	0.360	0.592	0.025

Table 66. Pooled pronghorn sex ratios by study area density. B:D=buck to doe ratio. High=high density study area, Medium=medium density study area, Low=low density study area. For a full description of each study area and unit please see chapter 1.

Comparisons	Ratio	Year	study area Density	Aug	Sept	P=value
Aug Vs Sept	F:D	Both	High	0.374	0.451	0.085
Aug Vs Sept	F:D	Both	Medium	0.372	0.433	0.325
Aug Vs Sept	F:D	Both	Low	0.269	0.334	0.181

Table 67. Calculation for age ratio sample size.

	2012 F:D High Den. study area Aug			**2012 F:D High Den. study area Sept**			**2013 F:D High Den. study area Aug**			**2013 F:D High Den. study area Sept**	
	F:D Avg	Diff		F:D Avg	Diff		F:D Avg	Diff		F:D Avg	Diff
20	0.68	-0.09	20	0.71	0.12	20	0.76	-0.01	20	0.57	-0.04
40	0.74	-0.07	40	0.63	-0.03	40	0.77	-0.08	40	0.59	0.05
60	0.80	0.00	60	0.64	-0.04	60	0.84	0.02	60	0.56	-0.01
70	0.79	-0.01	70	0.67	-0.01	70	0.82	0.01	70	0.57	0.00
80	0.80	0.02	80	0.68	0.00	80	0.81	0.05	80	0.56	0.06
90	0.79	-0.03	90	0.68	-0.01	90	0.78	-0.01	90	0.53	-0.06
100	0.81	-0.01	100	0.68	0.01	100	0.79	0.00	100	0.57	0.02
110	0.81	-0.06	110	0.68	0.01	110	0.78	0.02	110	0.56	-0.03
120	0.86	0.02	120	0.67	0.02	120	0.77	-0.05	120	0.57	-0.01

130	0.84	-0.03	130	0.66	-0.02	130	0.81	0.02	130	0.58	0.01
140	0.86	0.00	140	0.67	0.00	140	0.79	0.00	140	0.57	0.00

	2012 F:D Med. Den. study area Aug			**2012 F:D Med. Den. study area Sept**			**2013 F:D Med. Den. study area Aug**			**2013 F:D Med. Den. study area Sept**	
	F:D Avg	Diff		F:D Avg	Diff		F:D Avg	Diff		F:D Avg	Diff
20	0.95	-0.06	20	0.32	-0.30	20	0.74	0.13	20	0.44	-0.37
40	1.01	0.06	40	0.41	-0.29	40	0.65	0.00	40	0.61	-0.04
60	0.95	0.01	60	0.53	0.03	60	0.65	-0.07	60	0.63	-0.01
70	0.94	0.00	70	0.51	-0.04	70	0.69	0.00	70	0.64	0.05
79	0.93	0.00	80	0.53	0.00	80			80	0.61	0.00
90			90			90			90		
100			100			100			100		

	2012 F:D Low Den. study area Aug			**2012 F:D Low Den. study area Sept**			**2013 F:D Low Den. study area Aug**			**2013 F:D Low Den.study area Sept**	
	F:D Avg	Diff		F:D Avg	Diff		F:D Avg	Diff		F:D Avg	Diff
20	0.33	-0.75	20	0.22	-0.36	20	0.42	-0.36	20	0.14	-0.75
40	0.45	-0.75	31	0.30	1.00	32	0.57	1.00	30	0.24	1.00
60			60			60			60		
70			70			70			70		

Table 68. Calculation for sex ratio sample size.

	2012 B:D High Den. study area Aug			**2012 B:D High Den. study area Sept**			**2013 B:D High Den. study area Aug**			**2013 B:D High Den. study area Sept**	
	B:D Avg	Diff		B:D Avg	Diff		B:D Avg	Diff		B:D Avg	Diff
20	0.27	0.10	20	0.48	0.06	20	0.26	-0.38	20	0.52	0.11
40	0.25	-0.20	40	0.45	0.00	40	0.36	-0.09	40	0.46	-0.10
60	0.30	-0.02	60	0.45	0.04	60	0.40	0.05	60	0.51	0.03
70	0.30	0.00	70	0.43	-0.04	70	0.38	0.02	70	0.49	0.04
80	0.30	-0.03	80	0.45	-0.02	80	0.37	-0.04	80	0.47	0.04
90	0.31	-0.05	90	0.46	0.02	90	0.39	0.02	90	0.46	0.02
100	0.33	-0.04	100	0.45	0.02	100	0.38	-0.02	100	0.44	0.01
110	0.34	0.02	110	0.44	0.02	110	0.39	-0.01	110	0.44	-0.03
120	0.33	0.03	120	0.44	0.01	120	0.39	0.01	120	0.45	-0.06
130	0.32	0.01	130	0.43	0.01	130	0.39	0.01	130	0.48	0.01
140	0.32	1.00	140	0.43	1.00	140	0.38	1.00	140	0.47	1.00

	2012 B:D Med. Den. study area Aug			**2012 B:D Med. Den. study area Sept**			**2013 B:D Med. Den. study area Aug**			**2013 B:D Med. Den. study area Sept**	
	B:D Avg	Diff		B:D Avg	Diff		B:D Avg	Diff		B:D Avg	Diff
20	0.27	0.03	20	0.38	0.00	20	0.38	0.27	20	0.42	0.04
40	0.27	-0.06	40	0.38	-0.10	40	0.28	-0.27	40	0.41	-0.05
60	0.28	-0.01	60	0.42	0.02	60	0.36	-0.03	60	0.42	-0.05
70	0.29	-0.07	70	0.41	0.00	70	0.37	-0.02	70	0.44	0.00

80	0.31	-0.07	80	0.41	-0.01	80	0.38	0.00	80	0.45	-0.02
90	0.33	-0.03	90	0.41	-0.07	90	0.38	-0.02	90	0.45	0.06
100	0.34	-0.03	100	0.44	-0.02	100	0.38	-0.03	100	0.43	0.03
110	0.35	0.00	110	0.45	0.01	110	0.40	1.00	110	0.41	-0.02
120	0.35	0.00	120	0.44	-0.01	120			120	0.43	0.01
130	0.35	0.00	130	0.45	0.01	130			130	0.42	0.00
140	0.35	1.00	140	0.44	1.00	140			140	0.42	1.00

	2012 B:D Low Den. study area Aug			**2012 B:D Low Den. study area Sept**			**2013 B:D Low Den. study area Aug**			**2013 B:D Low Den. study area Sept**	
	B:D Avg	Diff		B:D Avg	Diff		B:D Avg	Diff		B:D Avg	Diff
20	0.23	0.11	20	0.33	0.06	20	0.31	-0.02	20	0.39	0.09
46	0.20	1.00	36	0.31	1.00	40	0.31	1.00	36	0.36	1.00
46			60			46			60		
70			70			70			70		

Figure 1. Black Hills of South Dakota deer study area and deer study area 1.

Figure 2. Black Hills of South Dakota deer sub units.

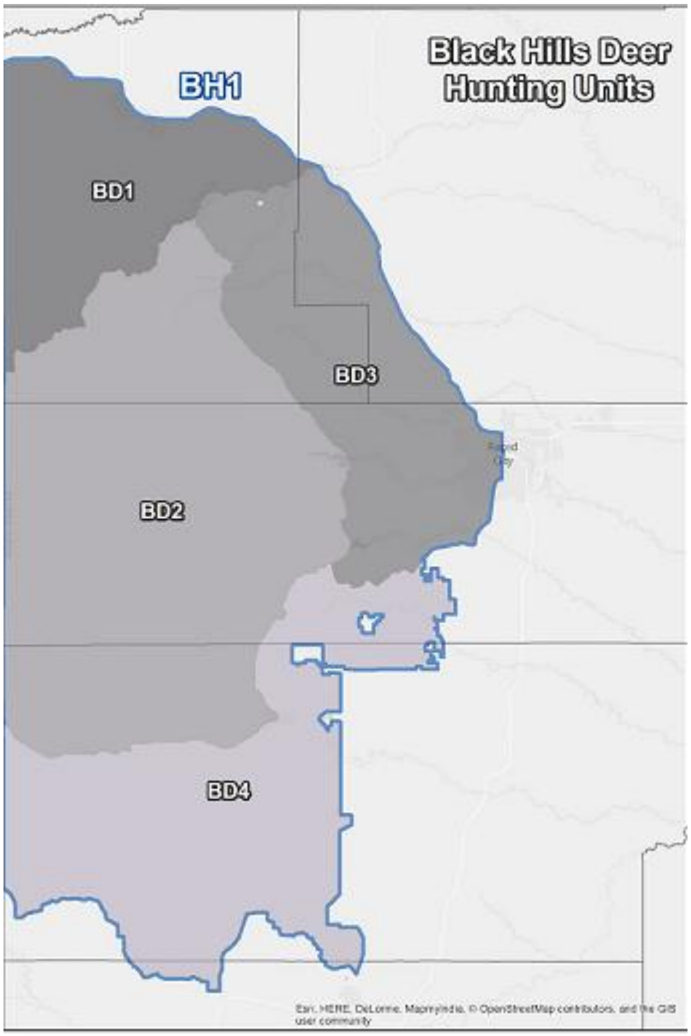


Figure 3. Deer study areas in Western South Dakota.

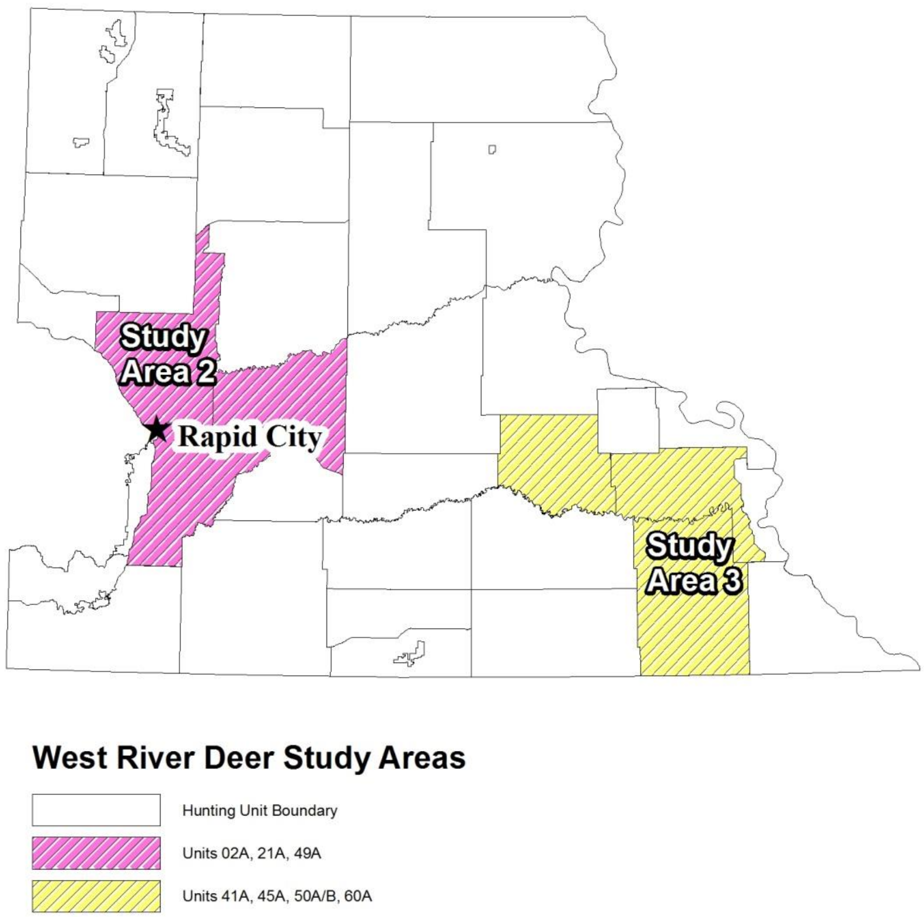


Figure 4. Deer study areas in Eastern South Dakota.

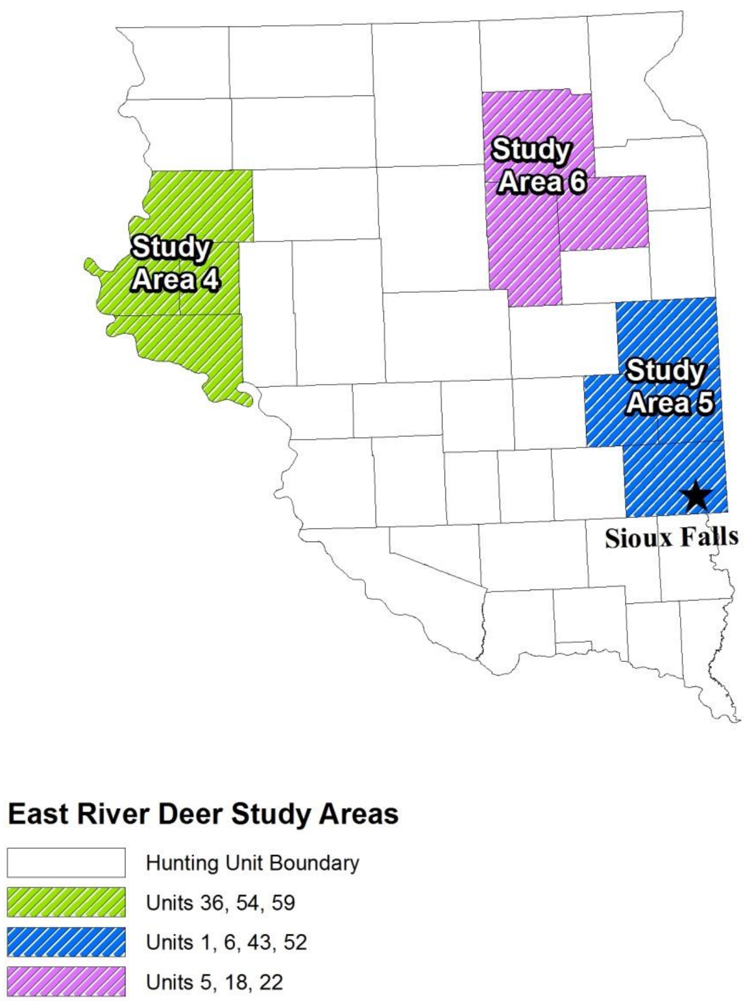


Figure 5. Pronghorn study areas in Western South Dakota.

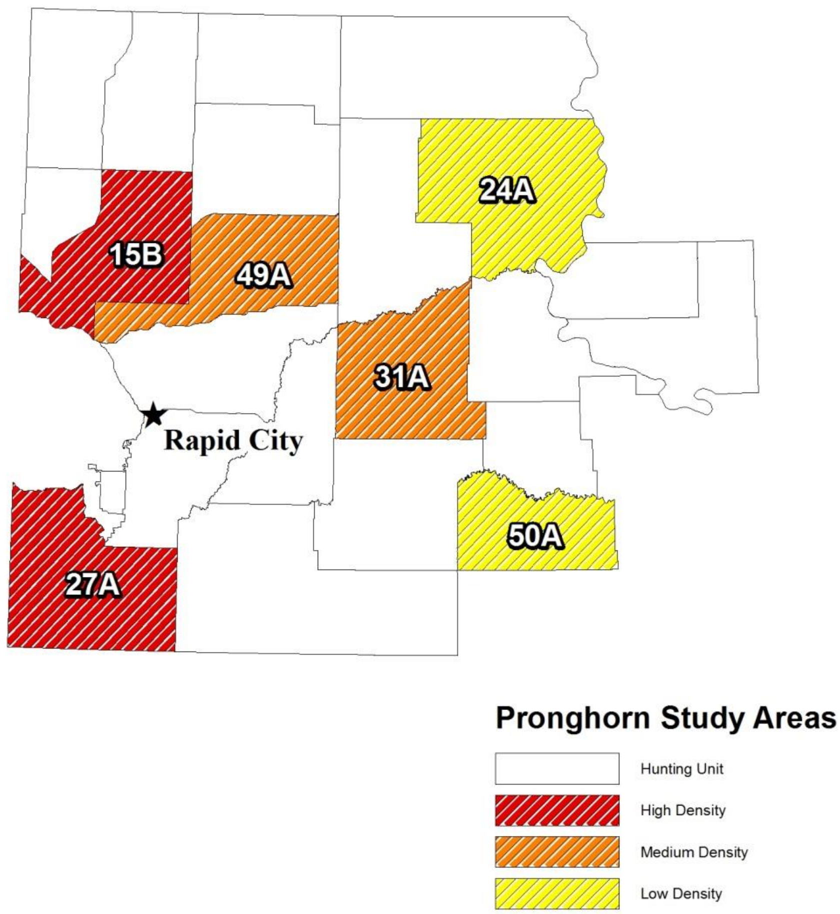


Figure 6: The total number of white-tailed deer by age class during three sampling periods.

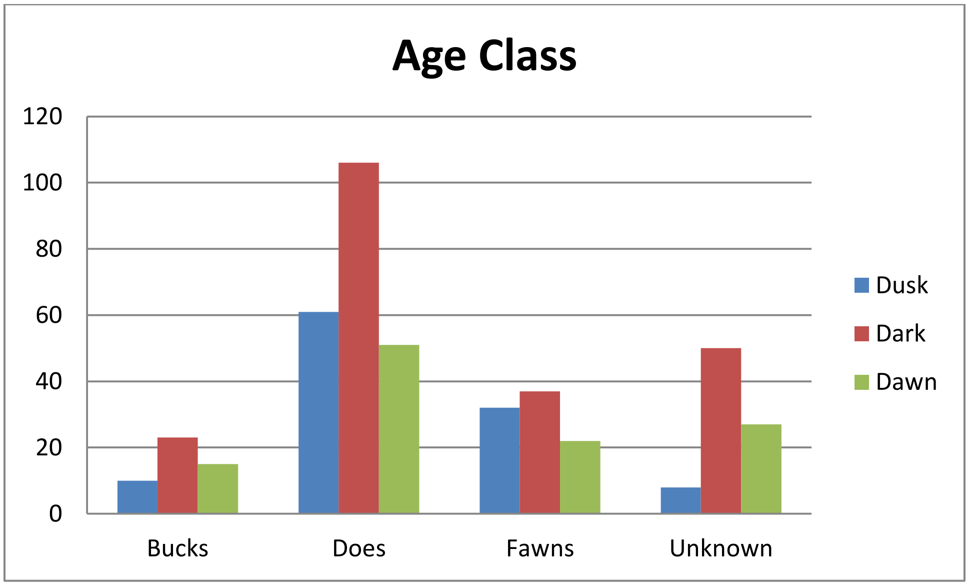


Figure 7: Number of deer observed within distance groups for each sampling time.

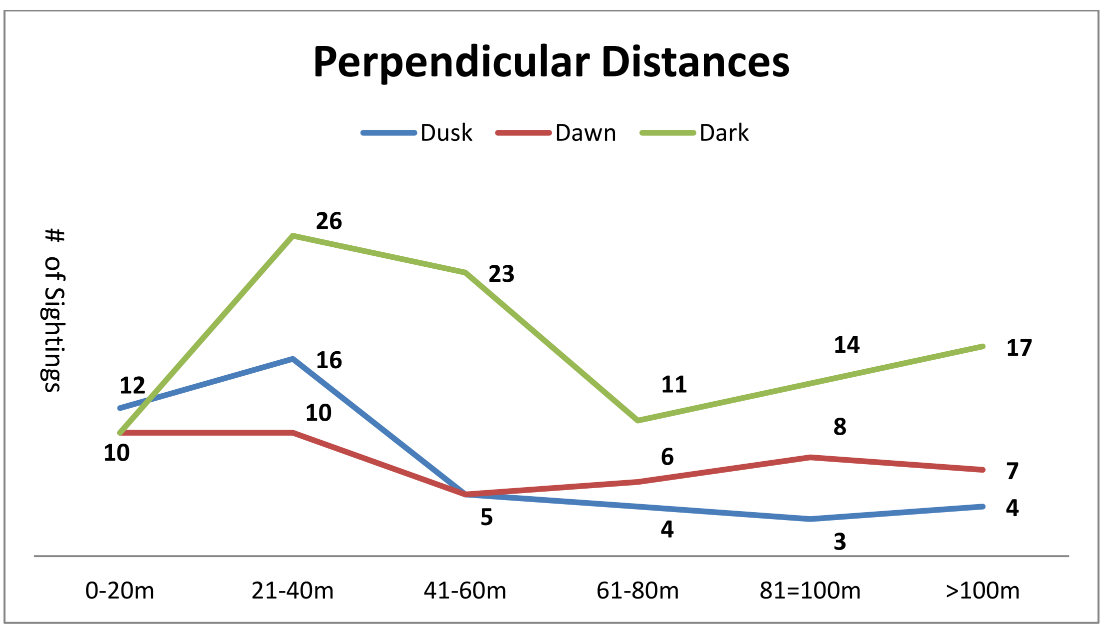


Figure 8**:** The mean time (min/km) to drive transects with one observer (SE = .352) and two observers (SE = .452).

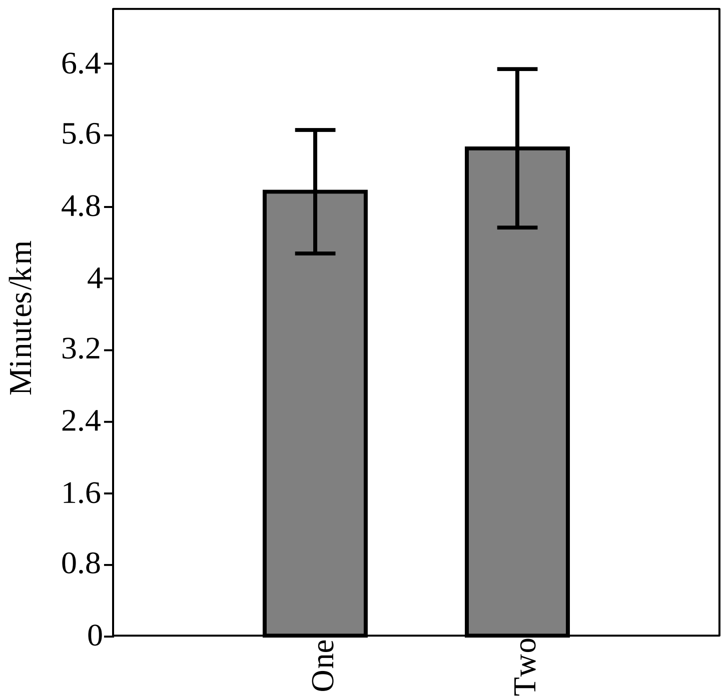


Figure 9. Black Hills of South Dakota transect locations.

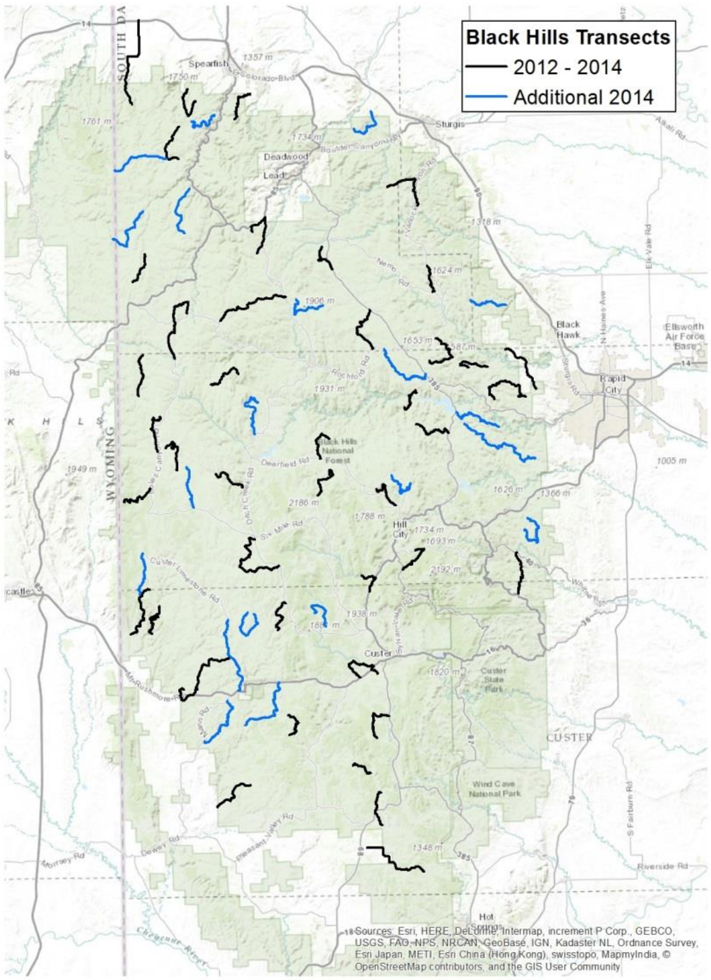
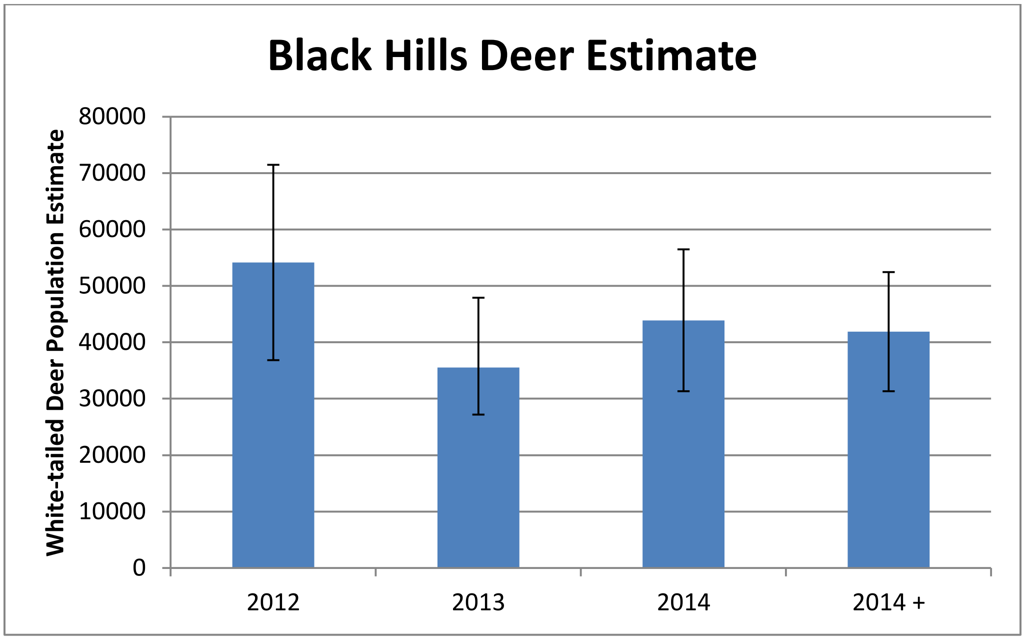
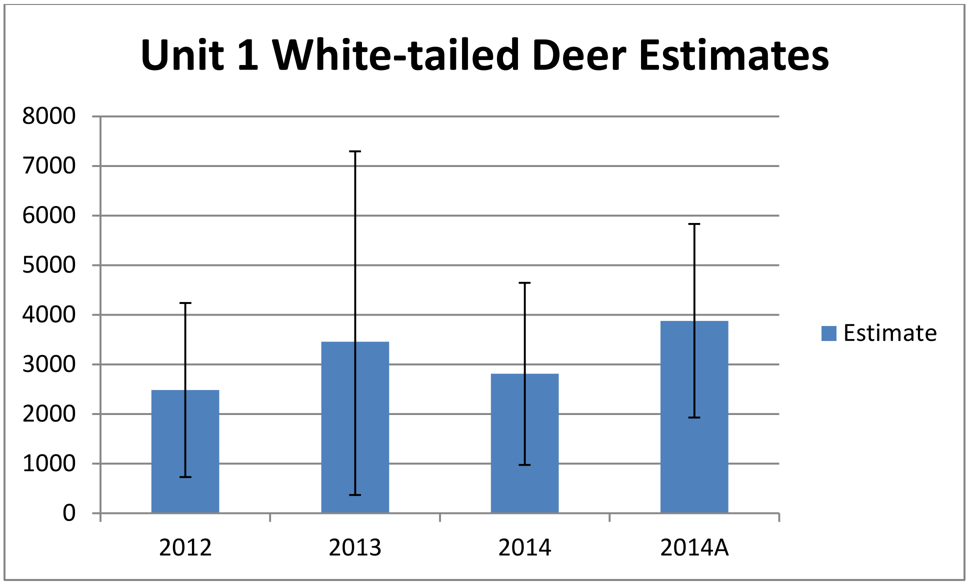


Figure 10. Density estimates of white-tailed deer in the Black Hills derived from Program R.



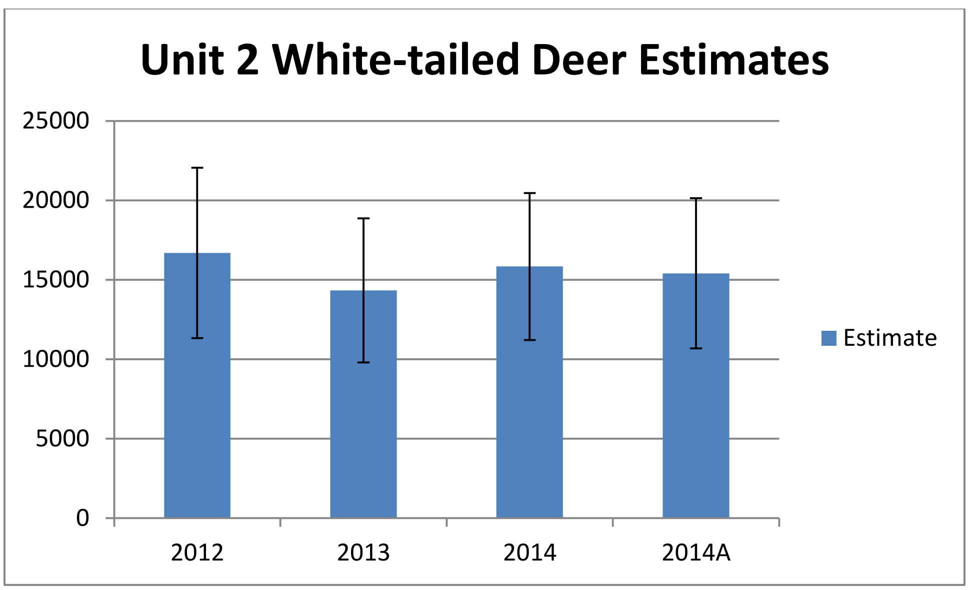
*2014A represents the original 42 transects plus the additional 20 transects.

Figure 11. Unit 1 density estimates for white-tailed deer in the Black Hills.



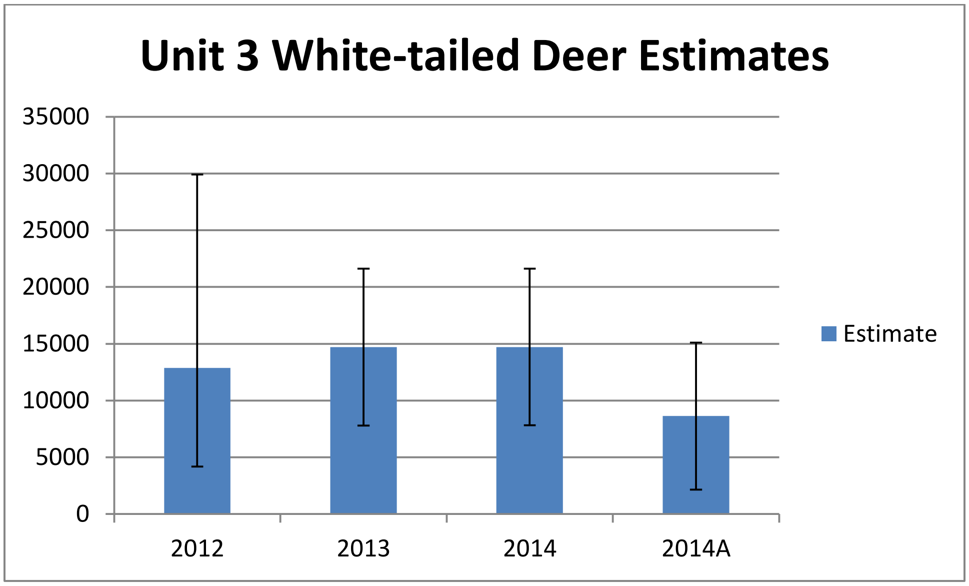
*2014A represents the original transects plus the additional 5 transects added to this unit in 2014.

Figure 12. Unit 2 density estimates for white-tailed deer in the Black Hills.



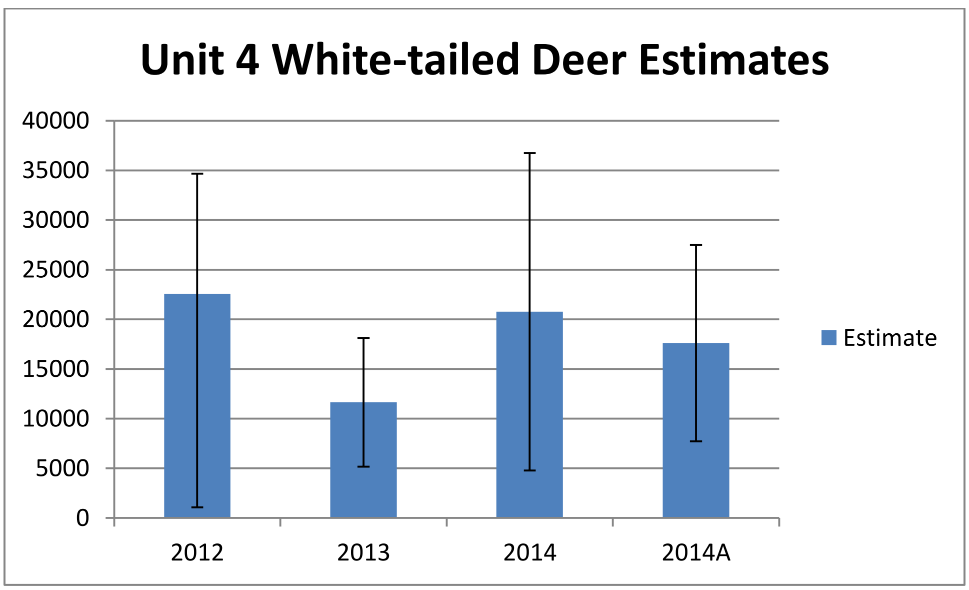
*2014A represents the original transects plus the additional 9 transects added to this unit in 2014.

Figure 14. Unit 3 density estimates for white-tailed deer in the Black Hills.



*2014A represents the original transects plus the additional 3 transects added to this unit in 2014.

Figure 15. Unit 4 density estimates for white-tailed deer in the Black Hills.



*2014A represents the original transects plus the additional 3 transects added to this unit in 2014.

Figure 16. 2012 deer in meadows detection probabilities for 2012 transects.

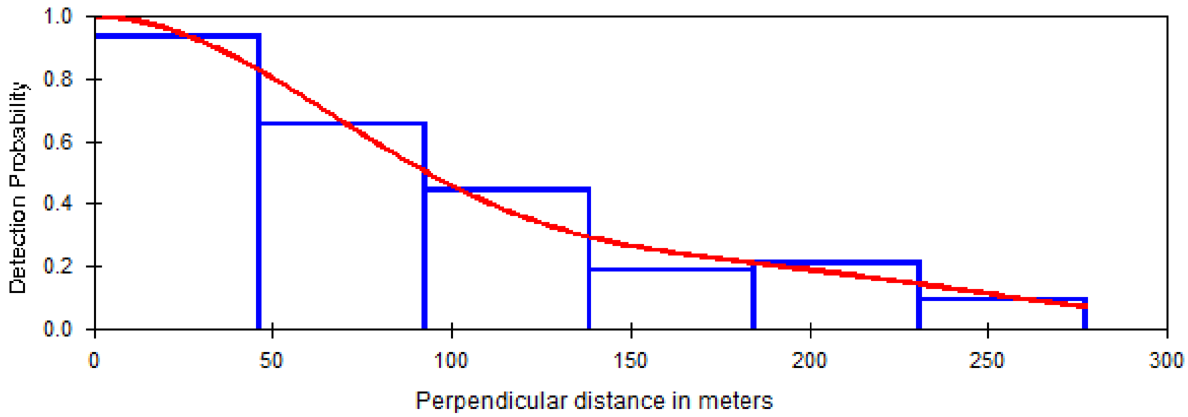


Figure 17. 2012 deer in trees detection probabilities for 2012 transects.

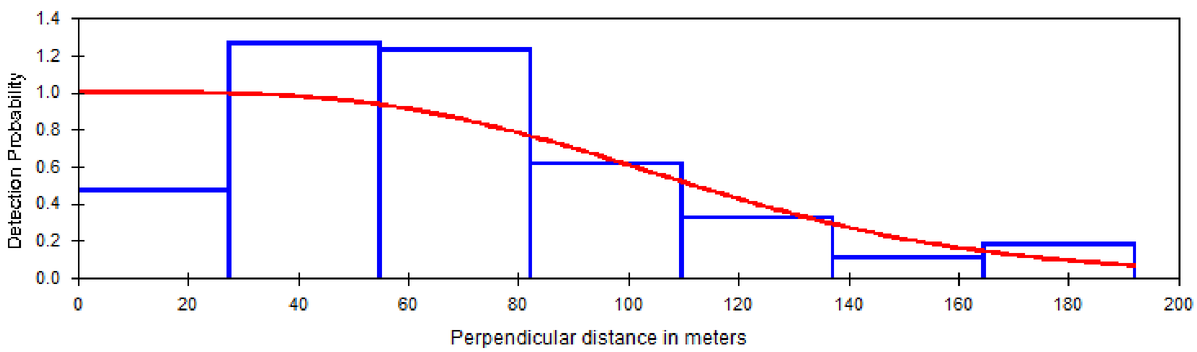


Figure 18. 2013 deer in meadows detection probabilities for 2013 transects.

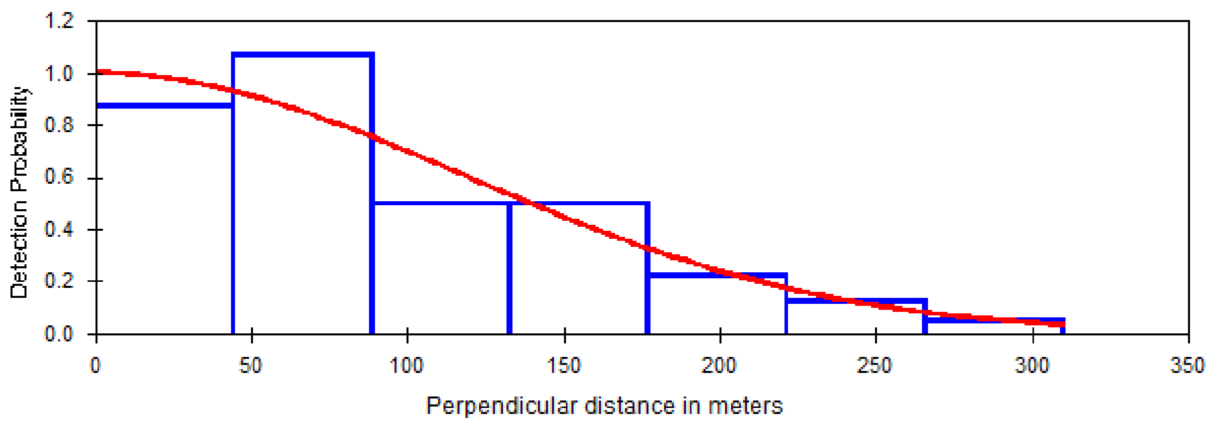


Figure 19. 2013 deer in trees detection probabilities for 2013 transects.

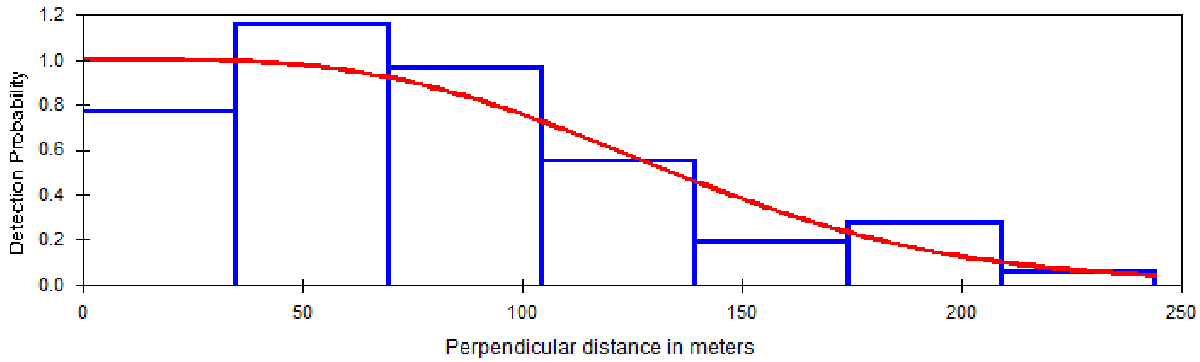


Figure 20. 2014 deer in meadows detection probabilities for 42 transects.

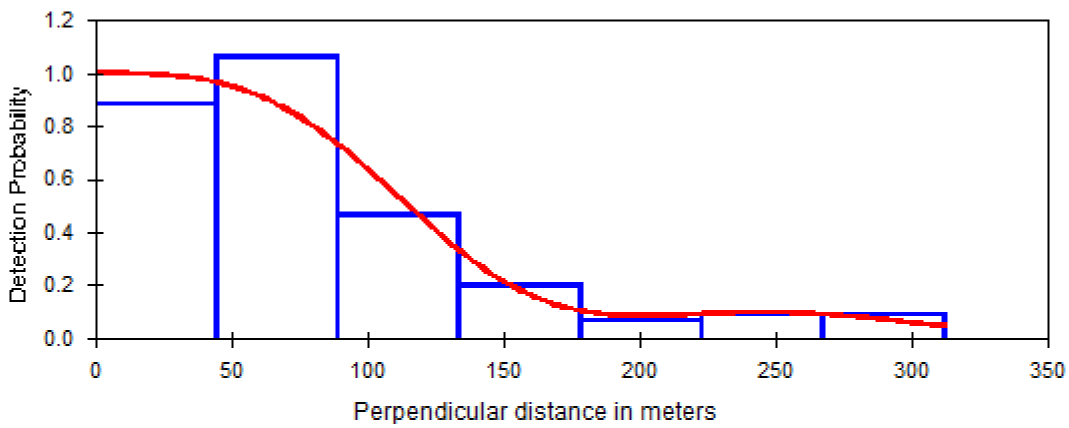


Figure 21. 2014 deer in trees detection probabilities for all 62 transects.

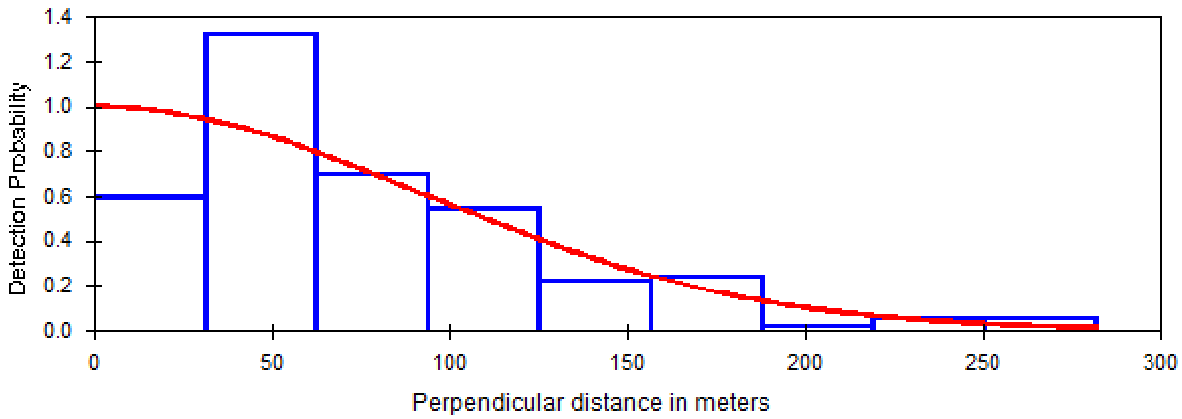


Figure 22. 2014 deer in trees detection probabilities for 42 transects.

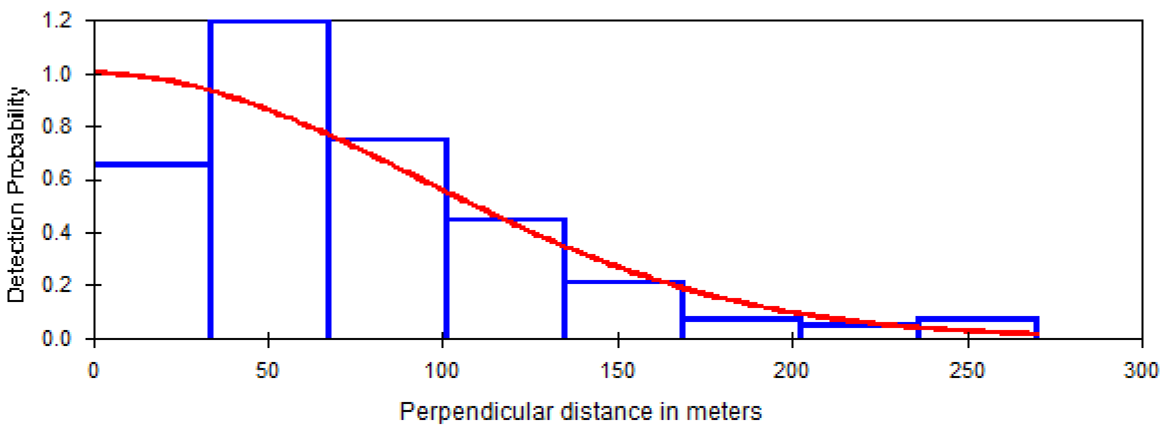
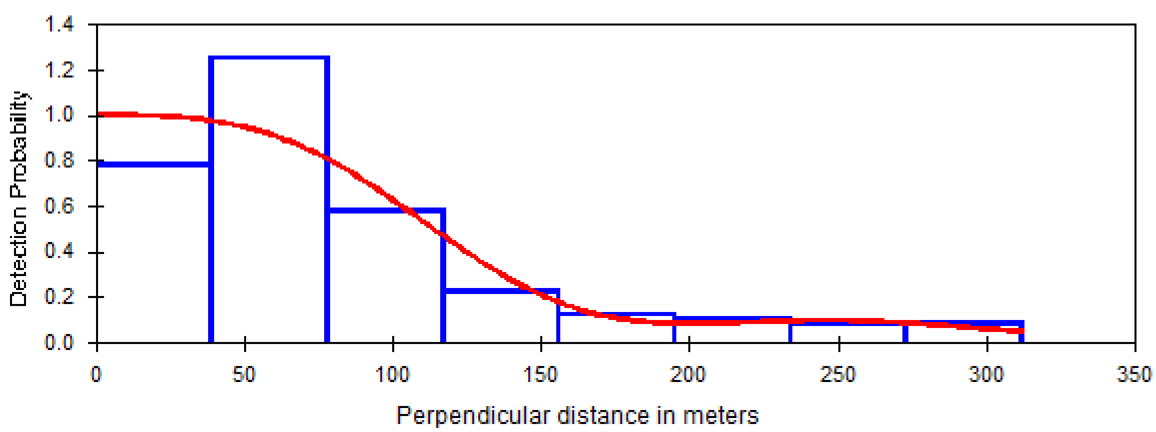


Figure 23. 2014 deer in meadows detection probabilities for 62 transects.



Appendix A. MCMC input Script for Program R

```
######### Set the inputs


reps <- 1e6

sigLevel = 1.96

TreeEst <-18838

TreeEstSE <-4043

MeadowEst <-18720

MeadowEstSE <-3391


###### Functions

CIsFromMCMC <- function(x,r){

        if(missing(r)){r=0}

        m <- mean(x)

        ll <- as.numeric(quantile(x, probs = c(.025)))

        ul <- as.numeric(quantile(x, probs = c(.975)))

        return (paste0(as.character(round(m,digits=r)),

        "; 95% CI = (",as.character(round(ll,digits=r)),

        ", ",as.character(round(ul,digits=r)),")")   )}



###### MCMC calcs


TreeEstMCMC <- rnorm(reps,mean=TreeEst, sd=TreeEstSE)

MeadowEstMCMC <- rnorm(reps, mean=MeadowEst, sd=MeadowEstSE)
```

```
TotEstMCMC <- (TreeEstMCMC)+(MeadowEstMCMC)


row1 <- c(CIsFromMCMC(TotEstMCMC,2))

row1
```

Appendix B. Route descriptions and notes.

#1- Start at 109.3a & 714 junction is starting point end point is where 109.1 and 268 meet

#2- Start at 294 head north on 112 then left/west onto 157(well graveled road) to 157.2b & stop there- route length about 5.0 mi

#3- Start at 536.1 RD on Vanocker rd >170.4 (galena rd)-stop @ Erickson/Galena Y in the road

#5-Start at 357.1G & 244 to 350 to end at 351

#6- Start at Experimental forest rd start @ hwy 385 to Rochford rd right on Rochford road stop at 231.2 rd

#7- Start off Nemo 414.6k >414.6G>through private gate take a left to Vanocker rd then take a left end at Dalton lake rd- route length about 3.2 miles' long

#9-Start at 474.1a to hwy 16 to 305 end at the 303 rd- route length about 3.6 mi

#10-Begin at 251.F drive to 385- route length about 4.3 mi

#11- -Start at Tinton rd on 177.1 rd go 2.2 mi veer right continue to next FS gate veer left after gate continue to main rd (106.1)- route length about 3.2m

#12-Enter 314.2 to 308/314.2h to 308 to 314.1 to fence line- route length about 3.3 mi

#13-Start at private (about .5mi before 109.4 rd) to end of 111.1A-route length about 3.5 mi

#15-Start at 626.1f (off 134.1) head S. to 626.1 on right continue to termination @ barb wire fence/gate- route length about 4.2 mi

#16-Start from 283 rd head south on 668 to US hwy 16 to 456.1F to 456.1G cross hwy 16 to 456.1E stop at large open area- route length about 3.8 mi

#17-Start at 296.1 to 296.1E to 469 to 4691.B end @291- route length about 4.1mi

#18-Start on road 781 on hwy 16 to 504 to 286 to 332. End where 332 Y's -route length about 5.4 mi

#19-Start at hwy 385 up to 201.2 (N bogus Jim rd) right at Merritt Estes to Nemo rd and end

#20-start at 333.2 rd from argyle go to 682 rd about 6miles- route length about 4mi

#21-Start at 239 (flag mtn rd) rd coming from Deerfield to 190 off 189.1 to 190.10 end at 1p&1o Y in road- route length about 3.5mi

#22-From 429 starting from FH17 (Deerfield rd) >443 where it veers right after rock quarry keep straight .03 mi &stop- route length about 3.6 miles

#25-Start at 231.5b 1.1 mi to 117.7e on left to 117.7 head S to 117.1 end after large meadow at cattle guard- route length about 7.8 mi

#26-Pull of on Nemo rd (Schroeder rd) to 7th cavalry rd - route length about 3.3 mi---

#28-Start at last house about 3.7mi from the junction of boles canyon and redbird canyon go 3.7 miles to 376.2B-- route length about 3.7mi

#29-Start on 726.1D (AKA TR8535) to trail 3535 to trail 3530 (AKA South Stots) stop exactly 6.0 mile in there is a T in the road— route length about 5.0 mi (+1)

#30-Start at 117.1 &264 intersection continue on 117.1 to 117.4c to of 117.4c- route length about 5.8mi

#31-Start at 559.1 on 385 then to Custer peak then to 213.1a (on right just past campground) > 4 way and right > end of road – route length about 3.3 mi

#32-Start at 313 &653 (fox ridge) continue to may rd triangle to 326.1G (it's in the center of the road triangle) continue to where road ends at a low spot. There is a house off to the left behind a rock. Going beyond this point will see your truck stuck—don't ask also don't do it.

#33-Start at 614 on FH17 (Deerfield rd coming from hill city) then head NW on FH17 to 389/194 to 389.1b end of road- route length about 3.6 miles or so in

#34-Start at campground on 385 & silver city road to silver city to bear gulch/251 rd to 251.1g end 1.1 miles in— route length about 4.5 mi

#35-Start at mouth of 627.1 to FH17 to 196.1c (Hanna road)-about 4.0 miles long

#36-Start at 313 & 315 intersection to 510 to 649.1d - route length about 3.2mi

#37-From Playhouse road from keystone to Iron mtn road then take a right up to Lakota lake entrance- route length about 4.4 miles

#38-From 291 go to 472 exit at 284- route length about 3.5mi

#39-Start at 721 road on 166(Norris peak) go to the end of 201.1b --

#40 - Enter from pass creek (273 rd) start @ 445 to 445.1a to end of road (route ends on side of hill- route length about3.2 mi

#41- Starting at interstate 90 head about 4 miles to bear gulch rd turn left 2.1 miles to forest service gate continue another 1.6 miles to barb wire gate end route- route length about 7.7 miles

#43-Start at 300.1f on Deerfield to 300 (East slate creek rd)   continue to 301 rd (six mile)

#44-Start at 214.15 to 134.1 end at 222.2c-

#45-Begin at FH17 (rochford rd) on Besant park side go until 231.5 (RC creek rd)- route length about 7.3mi

#46- Start at GPA across from spearfish field office go to FS/GPA gate continue about 3.6 mi to top of hill end at large tri-legged electric pole- route length about 5.4 miles

#47-start at 385 off ditch creek >385.1a follow trail through (super nasty two track) >294 come out at 591 rd off 294-turn left continue 2 mi about to 294.2m- route length about 3.7mi (+2)

#48-Begin 173.1a (log porch road)>197.2a >199.2b>199 (Schroeder rd) end at cattle guard on Schroeder

<u>Additional transects for 2014</u>

#3.2-- Start at intersection of Silver City Rd/Hwy 385, go west on Silver City. Turn R on Jenny Gulch Rd (FR261) at 2.2 mi; turn R to stay on 261 at 4.3 mi; end at 261/Rochford Rd at 6.4 mi

#5.2—Begin on FS285 (Saginaw road) @ interaction with 292 (Elliot road). Turn left on 285.1a 3 miles in. Turn right to end of road.   Route approx. 3.8 miles

#6.2 --Start at intersection of Rockerville Rd and FR 641 (43.93329, -103.36617), go E on 641. Turn right on 718.1B at 1.6 miles; turn R on 718 at 2.2 miles; turn R on Foster Gulch Rd (FR 372) at 4.0 miles; End at FR 372 and Rockerville Rd (43.91967, -103.37148) at 5.2 miles

#7.2-Start from 733.1 & 223.1. Follow 223.1 to 736.1. Go on 736.1 about 4.4 miles to down tree in the road. Keep on main road

#8.2-Begin on FS 117.1 (boles canyon) at intersection of Fs 265 (summit ridge) end at intersection of FS 117.1 (boles canyon) and 117.4a. Route about 4.0 miles long

#9.2—Start at the "Tree Farm" gate point 44.43194 -103.61916 and continue until you have to turn. Turn on road 542.1 @ confluence of 542.1/176.1. Go .8 miles turn on 542.1k go another .8 miles veer right on 699. Stop at gate

#10.2-- Point 10: Start at intersection of McCurdy Gulch (FR 165.1B)/Hwy 385, go E on 165.1B. Turn R at 0.1 mi to stay on 165.1B; turn sharp L to FR 772.1E at 0.7 mi; End at intersection of 772.1E/772.1H at 4.9 mi.

#14.2—Begin on cattle guard on Fs 283 (Antelope ridge) turn right on Fs 282 (mud springs) end at cattle guard on 282 about ½ mi from HWY 16. Route length 7 miles

#15.2 --Start at intersection of China Gulch Rd (FR 249) and FR 254 (43.97866, -103.56303), go West on 254. 254 becomes 254.1A without turning, then turns back to

254. Turn L on 389.1 (unsigned) at fork at 3.4 miles; turn L on 389 at T at 3.7 miles. End at intersection of Burnt Fork Rd (FR 389)/Deerfield Rd (43.96111, -103.60189).

#16.2—On 393.1 (Geranium) stay on main road to 393.1I about 2.9 miles in to split of 393.1I and 393.1K take 393.1I to 806.1 and end. About 5.7 miles long

#19.2—Start at cattle guard at TR8283 (GPS point 44.19820 -103.45161) go .7 miles veer to left and continue on TR 8283. Take Right on 8287 about 2 miles in and continue until point 44.1933 -103.39565 about 3.6 mi in.

#21.2—Start on FS747 (signal hill) at intersection of FS 284 (custer limestone) turn left on FS 282 (mud springs). End at intersection of FS282 (mudsprings) and FS 284 (Cuter limestone). Route 5.0 mi

#24.2-- Start at intersection of FR 294/FR 301.1J, go south on 301.1J; end at FR301/301.1J at 4.6 mi.

#28.2-- Start at intersection of Rochford Rd/Flag Mtn Rd. (FR189), go N on 189. Turn right on FR 599 at 1.5 mi; end at intersection of 599/599.1A at 4.8 mi.

#32.2-- Start at cattle guard at intersection of Victoria Lake (FR 159)/Sheridan Lake Rds, head West on 159. Turn R at 2.7 mi to stay on 159; L on 159 at 5.1 mi; L on 159 at 8.4 mi; end where FR 158 branches off in meadow at 9.1 mi. This end point is 1.7 mi from the start of the existing route at Custer Gulch/385

#33.2—Start at intersection of hwy 16 and 278 after .6 of a mile transition to 278.1a. Turn Right on 274.1b go 3.9 mi. Road becomes 274 at 4.6 mi in. Go through FS gate. Route ends at FS 277 about 6.9 mi in

#34.2—Start at 134.1 go 4 miles on 222.1

#35.2—Start on Custer crossing at 256.1L (Rocky Johnson RD) go to 256.1s about 4.6 miles end at 219.1 road

#37.2—Begin at intersection of 270 (Mann RD) and 270.1A continue through FS gate at about mi 1.8. End at intersection of FS 270.1a & FS 270.1B. Route about 3.9 mi

#40.2—Start at confluence of 134.1 &134.2 (44.42283 -103.93190). Follow log road to about 3.1 miles in and take the low road to GPS point 44.42474 -103.89317