USE OF THE USDA FOREST SERVICE GEOGRAPHIC INFORMATION SYSTEM FOR DETERMINING COVER TYPE USE BY WHITE-TAILED DEER

Christopher S. DePerno
Minnesota Department of Natural Resources
Farmland Wildlife Populations and Research Group
Madelia, MN 56062

Jonathan A. Jenks
Department of Wildlife and Fisheries Sciences
South Dakota State University
Brookings, SD 57007

Steven L. Griffin
South Dakota Department of Game, Fish and Parks
Rapid City, SD 57702

Robert W. Klaver
Department of Wildlife and Fisheries Sciences
South Dakota State University
Brookings, SD 57007
USGS EROS Data Center
Sioux Falls, SD 57198

ABSTRACT

Cover type use by white-tailed deer *(Odocoileus virginianus dacotensis)* in the central Black Hills of South Dakota was compared to the United States Department of Agriculture (USDA) Forest Service digital data using a Geographic Information System (GIS). Cover types were determined from observations of radiocollared deer and random locations and from corresponding point locations in the Forest Service digital data. Cover type information was collected at 3,145 white-tailed deer locations and 1,044 random locations. On winter range, cover types determined from observations of radiocollared deer included pine *(Pinus ponderosa),* pine-deciduous, aspen *(Populus tremuloides),* aspen-coniferous, burned pine, and meadows; cover types determined from Forest Service data included pine, aspen, grasslands, and private land. On summer range, cover types determined from observations of radiocollared deer included pine, pine-deciduous, aspen, aspen-coniferous, white spruce *(Picea glauca),* white spruce-deciduous, and meadows; cover types determined from Forest Service digital map data included pine, aspen, grasslands, and private land. Cover types used by white-tailed deer compared to the Forest Service data resulted in 42% agreement on summer range and 62% agreement on winter range. On winter and summer range, Forest Service data tended to overestimate ponderosa pine and aspen habitats used by white-tailed deer, while

failing to account for mixed (secondary) cover types. To improve the accuracy of habitat management decisions relative to white-tailed deer, the Forest Service GIS would be strengthened if mixed (secondary) cover type classifications were included in the database.

Keywords

Black Hills, cover type, GIS, habitat, Odocoileus virginianus, USDA Forest Service, white-tailed deer

INTRODUCTION

Geographic Information Systems (GIS) are a powerful set of tools for collecting, storing, retrieving, transforming, and displaying spatial data for a particular set of purposes (Burrough 1986). A GIS has many benefits and is particularly helpful in the analysis of spatial relationships within habitat selection analyses (Tomlin et al. 1988). A GIS automates the process of integrating maps and databases of diverse geographic features (Johnson 1995) and is an excellent tool for producing maps of different scales and colors (McLaren and Braun 1993).

The United States Department of Agriculture (USDA) Forest Service uses an overstory based GIS in forest management decisions. Because the white-tailed deer *(Odocoileus virginianus dacotensis)* herd has declined (DePerno 1998, DePerno et al. 2000) in the central Black Hills and because habitat selection is known (DePerno et al. In press) it is important to understand how cover type information contained in the Forest Service GIS compares to cover types used by white-tailed deer. This information will aid our understanding of the relationship between deer habitat use and the GIS presently used to make forest management decisions in the central Black Hills of South Dakota and Wyoming.

Effective management of wildlife populations largely depends on understanding and predicting habitat needs (Clark et al. 1993). In the northern Black Hills, it was determined that comparisons of habitat proportions within white-tailed deer home ranges and core areas did not differ from randomly derived home ranges (Nelson 1995, Nelson and Jenks 1995). Furthermore, these authors indicated the USDA Forest Service stand maps and site data lacked the detail necessary for defining habitat availability in the northern Black Hills. Data provided by the Forest Service consisted of a single cover type layer, whereas variables such as understory and cover-type mixes were absent (Nelson 1995, Nelson and Jenks 1995). Therefore, our objective was to compare cover types used by white-tailed deer (DePerno 1998, DePerno et al. In press) with the GIS presently used by the Forest Service to make critical management decisions within the central Black Hills.

STUDY AREA

The Black Hills is an isolated mountainous area in western South Dakota and northeast Wyoming that extends approximately 190 km north to south and 95 km east to west (Petersen 1984). Elevation of the Black Hills ranges from

973 - 2,202 m above mean sea level (Orr 1959, Turner 1974). Annual mean temperatures are typical of a continental climate and range from 5–9°C with extremes of -40–44°C (Thilenius 1972). Mean annual precipitation ranges from 45–66 cm (Orr 1959) and yearly snowfall may exceed 254 cm at higher elevations (Thilenius 1972).

The central Black Hills study area (43° 52' N to 44° 15' N – 104° 07' W to 103° 22' W) includes Pennington and Lawrence counties of South Dakota and Crook and Weston counties of Wyoming. The study area is composed of separate winter and summer ranges used by migratory white-tailed deer (DePerno 1998, DePerno et al. 2000, Griffin 1994, Griffin et al. 1995, 1999). Public land within the study area is managed by the United States Forest Service, within the Pactola, Harney, and Elk Mountain Ranger Districts, primarily for timber production and livestock grazing (1 June - 31 October).

Cover type on winter range consists primarily of monotypic stands of ponderosa pine *(Pinus ponderosa)* interspersed with stands of burned pine, quaking aspen *(Populus tremuloides),* and paper birch *(Betula papyrifera)* (McIntosh 1949, Orr 1959, Thilenius 1972, Richardson and Petersen 1974, Hoffman and Alexander 1987). Cover type on summer range consists primarily of ponderosa pine and white spruce *(Picea glauca)* interspersed with small stands of quaking aspen (McIntosh 1949, Orr 1959, Thilenius 1972, Richardson and Petersen 1974, Hoffman and Alexander 1987).

METHODS

White-tailed deer were captured during February and March 1993 - 1996 using modified, single-gate Clover traps (Clover 1956) baited with fresh alfalfa *(Medicago sativa)* hay. Deer were captured on four trap sites located northeast, northwest, and west of Hill City, South Dakota, on the McVey Burn deer winter range (Griffin et al. 1995, 1999, DePerno 1998). Adult and yearling female (n = 73) and male (n = 12) white-tailed deer were fitted with radiocollars (Telonics Inc., Mesa, Arizona; Lotek Engineering, Inc. Ontario, Canada), ear-tagged, aged by lower incisor wear, and released. Captured fawn white-tailed deer were ear-tagged and released (Griffin et al. 1995, DePerno 1998).

From July 1993 - July 1996, individual radiocollared deer were visually located from the ground 1 - 3 times per week. Deer were radiotracked at different time periods to maximize observations of diurnal activities (Hayes and Krausman 1993, Kernohan et al. 1996) and to obtain adequate sample sizes without violating the assumption of independent observations (White and Garrott 1990). Kernohan et al. (1996) and Hayes and Krausman (1993) demonstrated no differences between diurnal and 24-hour habitat use for white-tailed deer and mule deer, respectively. Within the central Black Hills, steep hills, deep draws, and long migration distances limited data collection activities to diurnal visual observations of deer and prevented the use of other techniques (e.g., triangulation) for obtaining radiolocations. Furthermore, because of the terrain and inaccessibility of many areas, attempts at spotlighting radiocollared deer to obtain nocturnal data were inefficient and represented a bias toward deer that were more accessible. Deer locations were plotted on 7.5-minute US-

GS topographical maps (scale, 1:24,000) and assigned Universal Transverse Mercator (UTM) coordinates (Edwards 1969, Grubb and Eakle 1988).

Because separate winter and summer ranges are used by migratory white-tailed deer (DePerno 1998, DePerno et al. 2000, Griffin 1994, Griffin et al. 1995, 1999), for analyses we stratified data according to seasonal elevation shifts made by each individual each year (Apps et al. 2001) and assigned each deer location and the corresponding habitat information to either winter or summer range. Habitat information was collected from 400-m^2, circular plots centered on each deer observation site (providing the location of the radiocollared deer was visually determined without disturbing the animal) and, to obtain a measure of relative habitat availability, at computer generated random locations sampled throughout the study area (Marcum and Loftsgaarden 1980, Kennedy 1992). Information recorded at each deer and random location included: UTM location (north and east), and dominant overstory tree species. If ≥2 tree species provided canopy cover, the species that provided the largest amount of cover was recorded as the primary forest species; remaining species were recorded as secondary species.

The GIS software PC ARC/INFO (Environmental Systems Research Institute, Inc., Redlands, CA) was used to compare cover types used by radiocollared white-tailed deer and random locations with cover types corresponding to the 1995 Black Hills GIS digital map data obtained from the USDA Forest Service. Basic map information for site polygons included area and cover type. Cover type information within the Forest Service GIS was primarily determined by aerial photograph delineation. The majority of land within the Forest Service data was owned by the USDA Forest Service with lesser amounts in private holdings.

Deer winter and summer ranges were derived by extracting regions above and below the 1829 m (6000 ft) contour from the National Elevation Dataset. The elevation coverage was then used to clip corresponding winter and summer range areas from the Forest Service digital data. Deer and random point locations were generated into separate coverages, overlaid, and intersected with the clipped winter and summer range coverages; thereby containing cover type information specific to each point location.

Cover types for deer and random point locations were pooled for all years of the study because of high fidelity to seasonal sites (Progulske and Baskett 1958, Ozoga et al. 1982, Tierson et al. 1985, Kennedy 1992, Nelson 1995). Cover types associated with deer and random locations were compared to the corresponding cover types described by the Forest Service data. A Chi-square test of homogeneity was used to determine differences between expected and observed distributions of habitats (Jelinski 1991, Kennedy 1992). Habitat use (i.e., deer) and availability (i.e., randoms) were compared to habitats in the Forest Service data (Neu et al. 1974, Byers et al. 1984, Kennedy 1992). Significance levels for 90% confidence intervals were determined using the Bonferroni method (Neu et al. 1974, Byers et al. 1984). All analyses were performed using SYSTAT (Wilkinson 1990).

RESULTS

In the central Black Hills, typical autumn migration for white-tailed deer is in a southeast direction from high elevation summer ranges to low elevation winter ranges and generally occurs between August and February (DePerno 1998, Griffin et al. 1999). Typical spring migration is in a northwest direction from low elevation winter ranges to high elevation summer ranges and generally occurs between 17 and 23 May (DePerno 1998, Griffin et al. 1999).

Between July 1993 and July 1996, cover type information was collected at 3,145 deer locations and, to obtain a measure of relative habitat availability, at 1,044 computer generated random locations sampled throughout the study area. Excluded from analyses were data on one radiocollared male that remained on winter range throughout the year and one radiocollared female that demonstrated an abnormal migration pattern (DePerno et al. 1997).

On winter range, white-tailed deer used areas that were predominantly pine or pine-deciduous (Table 1). Meadows, burned pine stands, aspen, and aspen-coniferous habitats accounted for ~17% of 1,538 locations. When deer locations were overlaid, the corresponding data provided by the Forest Service indicated that white-tailed deer primarily used areas dominated by pine, aspen, and private land (Table 1). On winter range, cover types used by white-tailed deer compared to the Forest Service data resulted in 62% agreement. On summer range, white-tailed deer used areas that were predominantly pine or pine-deciduous (Table 2). Spruce, spruce-deciduous, aspen, and aspen-coniferous habitats were used at moderate levels. When deer locations were overlaid, the corresponding data provided by the Forest Service indicated that white-tailed deer primarily used areas dominated by pine, aspen, and spruce (Table 2). On summer range, cover types used by white-tailed deer compared to the Forest Service data resulted in 42% agreement.

Because the Forest Service database did not account for secondary cover types (Tables 1, 2), we combined mixed stands with primary cover types prior to conducting analyses. During winter, cover characteristics (Tables 3, 4) varied for deer (χ^2 = 189.42, df = 4, $P < 0.001$) and random locations (χ^2 = 91.00,

Table 1. Cross-tab comparison of white-tailed deer and USDA Forest Service cover types for winter range in the central Black Hills, South Dakota and Wyoming, 1993-1996.

	USDA FOREST SERVICE COVER TYPE				
White-tailed Deer Cover Type	**Pine**	**Aspen**	**Grassland**	**Private**	**Total**
Pine	939	40	14	67	1060
Pine-Deciduous	189	13	2	8	212
Aspen	18	10	1	2	31
Aspen-Coniferous	21	8	0	2	31
Spruce	0	0	1	2	3
Burned Pine	109	0	1	0	110
Meadows	41	6	6	38	91
Total	*1317*	*77*	*25*	*119*	*1538*

Table 2. Cross-tab comparison of white-tailed deer and USDA Forest Service cover types for summer range in the central Black Hills, South Dakota and Wyoming, 1993-1996.

	USDA FOREST SERVICE COVER TYPE						
White-tailed Deer Cover Type	**Pine**	**Aspen**	**Spruce**	**Grass-land**	**Poa Grassland**	**Private**	**Total**
Pine	586	20	16	2	2	86	712
Pine-Deciduous	213	28	2	6	1	83	333
Aspen	26	31	0	0	0	32	89
Aspen-Coniferous	67	33	2	3	1	36	142
Spruce	118	7	57	4	1	29	216
Spruce-Deciduous	43	10	19	1	1	16	90
Burned Pine	1	0	0	0	0	0	1
Meadows	11	1	0	1	1	10	24
Total	*1065*	*130*	*96*	*17*	*7*	*292*	*1607*

Table 3. Comparison of cover characteristics for white-tailed deer locations on winter range in the central Black Hills, South Dakota and Wyoming, 1993-1996, as determined by deer use data and USDA Forest Service Geographical Information System (GIS) stand data.

Cover Type	**Deer Location Data (n = 1335)**	**Forest Service Data (90% CI) (n = 1335)**
Pine/Pine-Deciduous	89.66 +	85.32 (82.89-87.47)
Aspen/Aspen-Coniferous	4.05	5.17 (3.84-6.74)
Spruce/Spruce-Deciduous	0.30	0.00 (0.00-0.33)
Meadows	5.99 +	1.65 (0.93-2.63)
Private Land	0.00 -	7.87 (6.22-9.73)

Table 4. Comparison of cover characteristics for random locations on winter range in the central Black Hills, South Dakota and Wyoming, 1993-1996, as determined by random habitat data and USDA Forest Service Geographical Information System (GIS) stand data.

Cover Type	**Randoms (n = 483)**	**Forest Service Data (90% CI) (n = 483)**
Pine/Pine-Deciduous	81.78	80.12 (75.31-84.21)
Aspen/Aspen-Coniferous	4.76	3.93 (2.07-6.53)
Spruce/Spruce-Deciduous	1.24	0.41 (0.00-1.72)
Meadows	12.22 +	4.76 (2.69-7.54)
Private Land	0.00 -	10.56 (7.40-14.30)
Not Identified[a]	0.00	0.21 (0.00-1.36)

[a] dominant cover type not identified but determined to be water (WAT) by the USDA Forest Service GIS database.

df = 5, $P < 0.001$). Similarly, during summer, cover characteristics (Tables 5, 6) varied for deer (χ^2 = 270.16, df = 4, $P < 0.001$) and random locations (χ^2 = 93.99, df = 5, $P < 0.001$).

On winter range, white-tailed deer were located in pine and meadow habitats in proportions greater than the corresponding Forest Service data (Table 3). Meadows were categorized for random locations at greater levels than the corresponding Forest Service data (Table 4). On summer range, white-tailed deer were located in aspen and spruce areas in proportions greater than those occurring in Forest Service data, while using pine habitats less than those occurring in Forest Service data (Table 5). Spruce and meadows were categorized for random locations at greater levels than the corresponding Forest Service data (Table 6).

Table 5. Comparison of cover characteristics for white-tailed deer locations on summer range in the central Black Hills, South Dakota and Wyoming, 1993-1996, as determined by deer use data and USDA Forest Service Geographical Information System (GIS) stand data.

Cover Type	Deer Location Data (n = 1231)	Forest Service Data (90% CI) (n = 1231)
Pine/Pine-Deciduous	64.58 -	73.84 (70.78-76.68)
Aspen/Aspen-Coniferous	13.08 +	8.53 (6.75-10.54)
Spruce/Spruce-Deciduous	20.80 +	6.74 (5.16-8.57)
Meadows	1.54	1.63 (0.89-2.65)
Private Land	0.00 -	9.26 (7.41-11.34)

Table 6. Comparison of cover characteristics for random locations on summer range in the central Black Hills, South Dakota and Wyoming, 1993-1996, as determined by random habitat data and USDA Forest Service Geographical Information System (GIS) stand data.

Cover Type	Randoms (n = 561)	Forest Service Data (90% CI) (n = 561)
Pine/Pine-Deciduous	71.84	75.58 (70.87-79.73)
Aspen/Aspen-Coniferous	5.88	3.74 (2.04-6.07)
Spruce/Spruce-Deciduous	9.80 +	5.88 (3.70-8.64)
Meadows	12.48 +	5.70 (3.56-8.43)
Private Land	0.00 -	8.56 (5.91-11.74)
Not Identified[a]	0.00	0.54 (0.04-1.77)

[a] dominant cover type not identified but determined to be water (WAT) and non-vegetated sites (NFL) by the USDA Forest Service GIS database.

DISCUSSION

Quality of GIS analyses depends as much on the accuracy of the digital maps as the habitat factors (Donovan et al. 1987, Lyon 1983, Stoms et al. 1992, Nelson 1995 Nelson and Jenks 1995). Different levels of map and data detail may be necessary to obtain satisfactory modeling results and the effectiveness of a GIS as a management tool depends largely on the quality of data used (Stoms et al. 1992, Nelson and Jenks 1995). However, erroneous models could result from inaccurate animal locations and misclassification of habitat types (Donovan et al. 1987, Lyon 1983, Stoms et al. 1992).

On winter and summer range, Forest Service data tended to overestimate ponderosa pine and aspen habitats used by white-tailed deer, while failing to account for mixed (secondary) cover types (Tables 1, 2). For instance, in the Forest Service database pine-deciduous and aspen-coniferous stands are not distinguishable from pine or aspen stands, respectively. Additionally, the Forest Service data failed to characterize burned pine habitats. Meadow habitats, although not specifically designated in the Forest Service data, were characterized as grass habitats (GRA) and bluegrass dominated habitats (GPO). Furthermore, habitats on private lands were not identified in the Forest Service database (Tables 1–6).

On winter range, when mixed (secondary) cover types were combined with primary cover types, pine habitats were more abundant at deer locations than in the corresponding Forest Service data (Table 3). On winter range, meadows were more abundant at deer and random locations than in corresponding Forest Service data (Tables 3, 4). On summer range, aspen, spruce, and meadow habitats were more abundant at deer and random sites than in the corresponding Forest Service data (Tables 5, 6). Many of the meadows and aspen stands occupied by white-tailed deer were small and may not have been evident in the aerial photographs used by the Forest Service or too large of a minimum mapping unit was used to develop their GIS data base. Moreover, it may be difficult to distinguish spruce and ponderosa pine from aerial photographs.

Cover types classified by the Forest Service lack the detail necessary for defining habitats used by white-tailed deer and available at random sites in the central Black Hills (Tables 1, 2). Deer and random data included mixed-cover characteristics that were absent in the Forest Service digital data. Such under representation of habitats could be related to a failure to recognize the finer scale habitat features that occur within a larger habitat type (Stoms et al. 1992). Poor quality of cover types classified in the Forest Service GIS should be recognized and accounted for in future analyses and management decisions. However, improvements have recently been made to the Forest Service database. Nevertheless, if mixed cover types are not considered in habitat classification, a stand with secondary cover layers could be labeled as one uniform stand (Nelson 1995, this study). To improve the accuracy of habitat management decisions relative to white-tailed deer, the Forest Service GIS would be strengthened if mixed (secondary) cover type classification were included in the database or if a smaller minimum mapping unit was used. In the spirit of cumulative effects analysis as required by the National Environmental Protection Act (NEPA) and ecosystem management (Boyce and Haney 1997), we rec-

ommend gathering data in the Black Hills without regard to landownership (i.e., the USDA Forest Service should gather information on public and private lands).

ACKNOWLEDGMENTS

This study was supported by Federal Aid to Wildlife Restoration Fund, Project W-75-R through the South Dakota Department of Game, Fish and Parks (Study Numbers 7563 and 7564). Field assistance was provided by D. A. Flory, J. McCormick, and D. Knowlton. We thank L. D. Flake, K. F. Higgins, R. Johnson, G. E. Larson, and J. Vandever for their review of earlier versions of this manuscript. We wish to thank the United States Forest Service, Pactola and Harney Ranger Districts and all landowners that allowed access to their property throughout this study.

LITERATURE CITED

Apps, C. D., B. N. McLellan, T. A. Kinley, and J. P. Flaa. 2001. Scale-dependent habitat selection by mountain caribou, Columbia Mountains, British Columbia. The Journal of Wildlife Management 65:65-77.

Boyce, M. S., and A. Haney, editors. 1997. Ecosystem management: Applications for sustainable forest and wildlife resources. Yale University Press, New Haven, Connecticut, USA.

Burrough, P. A. 1986. Principles of geographical information systems for land resources assessment. Monographs on Soil and Resource Survey No. 12. Clarendon Press, Oxford, 193 pp.

Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. The Journal of Wildlife Management 48:1050-1053.

Clark, J. D., J. E. Dunn, and K. G. Smith. 1993. A multivariate model of female black bear habitat use for a geographic information system. The Journal of Wildlife Management 57:519-526.

Clover, M. R. 1956. Single-gate deer trap. California Fish and Game 42:199-201.

DePerno, C. S. 1998. Habitat selection of a declining white-tailed deer herd in the central Black Hills, South Dakota and Wyoming. Dissertation, South Dakota State University, Brookings, South Dakota, USA.

DePerno, C. S., S. L. Griffin, J. A. Jenks, and L. A. Rice. 1997. Unusual migration by a white-tailed deer fawn. Prairie Naturalist 29:93-97.

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

DePerno, C. S., J. A. Jenks, S. L. Griffin, L. A. Rice, and K. F. Higgins. In press. White-tailed deer habitats in the central Black Hills. Journal of Range Management.

Donovan, M. L., D. L. Rabe, C. E. Olson, Jr. 1987. Use of geographic information systems to develop habitat suitability models. Wildlife Society Bulletin 15:574-579.

Edwards, R. L. 1969. Archaeological use of the Universal Transverse Mercator grid. American Antiquity 34:180-182.

Griffin, S. L. 1994. Seasonal movements and home range of white-tailed deer in the central Black Hills, South Dakota, 1993. Pittman-Robertson Report W-75-R-35. South Dakota Department of Game, Fish and Parks, Pierre, South Dakota, USA.

Griffin, S. L., C. S. DePerno, J. A. Jenks, L. A. Rice, and D. A. Flory. 1995. Capture success of white-tailed deer in the central Black Hills, South Dakota. Proceedings of South Dakota Academy of Science 74:71-76.

Griffin, S. L., L. A. Rice, C. S. DePerno, and J. A. Jenks. 1999. Seasonal movements and home ranges of white-tailed deer in the central Black Hills, South Dakota and Wyoming, 1993–97. South Dakota Department of Game, Fish and Parks, Pittman-Robertson Game Report W-75-R-34, Pierre, South Dakota, USA.

Grubb, T. G., and W. L. Eakle. 1988. Recording wildlife locations with the Universal Transverse Mercator (UTM) Grid System. USDA Forest. Service Research Paper RM-483. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado, USA.

Hayes, C. L., and P. R. Krausman. 1993. Nocturnal activity of female desert mule deer. The Journal of Wildlife Management 57:897-904.

Hoffman, G. R., and R. R. Alexander. 1987. Forest vegetation of the Black Hills National Forest of South Dakota and Wyoming: a habitat type classification. United States Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

Jelinski, D. E. 1991. On the use of chi-square analyses in studies of resource utilization. Canadian Journal of Forest Research 21:58-65.

Johnson, R. R. 1995. Demographics of eastern South Dakota wetlands and wetland basins and techniques for estimating the area and number of wetland basins. Dissertation, South Dakota State University, Brookings. USA.

Kennedy, J.F. 1992. Habitat selection by female white-tailed deer in the northern Black Hills, South Dakota and Wyoming. M.S. Thesis, South Dakota State University, Brookings, South Dakota, USA.

Kernohan, B. J., J. A. Jenks, D. E. Naugle, and J. J. Millspaugh. 1996. Estimating 24-h habitat use patterns of white-tailed deer from diurnal use. Journal of Environmental Management 48:299-303.

Lyon, J. G. 1983. Landsat-derived land-cover classification for locating potential kestrel nesting habitat. Photogrammetric Engineering and Remote Sensing 49:245-250.

Marcum, C. L., and D. O. Loftsgaarden. 1980. A nonmapping technique for studying habitat preferences. The Journal of Wildlife Management 44:963-968.

McIntosh, A. C. 1949. A botanical survey of the Black Hills of South Dakota. Black Hills Engineer 28:1–74.

McLaren, S. B. and J. K. Braun. 1993. GIS applications in mammalogy. Oklahoma Museum of Natural History and the Carnegie Museum of Natural History, 41 pp.

Nelson, B. E. 1995. Use of Geographic Information system for determining white-tailed deer habitat use in the Northern Black Hills of South Dakota and Wyoming. M.S. Thesis. South Dakota State University, Brookings, South Dakota, USA.

Nelson, B. E., and J. A. Jenks. 1995. Use of Geographic Information system for determining white-tailed deer habitat use in the Northern Black Hills of South Dakota, USA. Pp. 672-675, *in* Integrating people and wildlife for a sustainable future. (J.A. Bissonette and P.R. Krausman, eds.). Proceedings of the First International Wildlife Management Congress, The Wildlife Society, Bethesda, Maryland, USA.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. The Journal of Wildlife Management 38:541-545.

Orr, H. K. 1959. Precipitation and streamflow in the Black Hills. United States Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

Ozoga, J. J., L. J. Verme, and C. S. Bienz. 1982. Parturition behavior and territoriality in white-tailed deer: impact on neonatal mortality. The Journal of Wildlife Management 46:1-11.

Petersen, L. E. 1984. Northern Plains. Pp. 441-448, in White-tailed Deer: Ecology and Management. (L. K. Halls ed.). The Wildlife Management Institute, Washington, D.C., USA.

Progulske, D. R., and T. S. Baskett. 1958. Mobility of Missouri deer and their harassment by dogs. The Journal of Wildlife Management 22:184-192.

Richardson, A. H., and L. E. Petersen. 1974. History and Management of South Dakota Deer. South Dakota Department of Game, Fish and Parks, Pierre, South Dakota, USA.

Stoms, D. M., F. W. Davis, and C. B. Cogan. 1992. Sensitivity of wildlife habitat models to uncertainties in GIS data. Photogrammetric Engineering and Remote Sensing 58:843-850.

Thilenius, J. F. 1972. Classification of deer habitat in the ponderosa pine forest of the Black Hills, South Dakota. United States Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

Tierson, W. C., G. F. Mattfeld, R. W. Sage, and D. F. Behrend. 1985. Seasonal movements and home ranges of white-tailed deer in the Adirondacks. The Journal of Wildlife Management 49:760-769.

Tomlin, C. D., S. H. Berwick, and S. M. Tomlin. 1988. The use of computer graphics in deer habitat evaluation. Pages 212-218 in W. J. Ripple, ed. Geographic information systems for resource management: a compendium. American Society for Photogrammetry and Remote Sensing, Virginia.

Turner, R. W. 1974. Mammals of the Black Hills of South Dakota and Wyoming. Publication of the Museum of Natural History. University of Kansas, Lawrence, Kansas, USA

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, New York, New York, USA.

Wilkinson, L. 1990. Systat: the system for statistics. Systat, Inc. Evanston, Illinois, USA.