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ABSTRACT Winter habitat and resource use of white-tailed deer (*Odocoileus virginianus*) have been studied extensively throughout their northern range. However, limited information exists on deer use of late season standing corn. We evaluated standing corn use by female white-tailed deer on winter range in north-central South Dakota during winter 2005–2006. Results indicate that cover type selection occurred at the population ($P < 0.001$) and home range ($P < 0.001$) levels. Population level analysis indicated selection for standing corn ($\hat{w}$ = 4.31) and Conservation Reserve Program (CRP) grasslands ($\hat{w}$ = 2.81). Similarly, at the home range level, deer selected for standing corn ($\hat{w}$ = 1.35) and CRP grasslands ($\hat{w}$ = 1.44). Deer disproportionately increased use of standing corn and CRP as habitat availability increased. Moreover, deer used wetlands and forested habitat in proportion to availability. In this region of the Northern Great Plains, availability and distribution of traditional cover habitats (i.e., forested and wetland habitats) is limited. We speculate that deer selected late season standing corn to optimize thermoregulatory and forage requirements, as well as visual protection against potential predators.

KEY WORDS eigenanalysis, Northern Great Plains, *Odocoileus virginianus*, resource selection, standing corn, South Dakota, white-tailed deer

Resource selection and use are important to the study of animal ecology (Johnson 1980, Orians and Wittenberger 1991), behavior, and population dynamics (Mysterud and Ims 1998). Studying cover type selection can identify biological requirements, forecast effects of habitat changes, enable protection for key areas and plant species, and evaluate hypotheses concerning underlying ecological processes (Lubin et al. 1993, Arthur et al. 1996). Usable resources must sustain animal populations (Manly et al. 2002) and provide for successful reproduction (Mysterud and Ims 1998). In addition, usable resources are an important component of fitness and provide insight into the nature of a species and the requirement for survival (Franklin et al. 2000, Manly et al. 2002, Gillies et al. 2006).

Habitat selection may take place at several spatial scales (Johnson 1980, Orians and Wittenberger 1991) and multiscale studies have become more common (Cooper and Millspaugh 2001, Manly et al. 2002). Johnson (1980) defined selection as first-order selection, selection of a physical or geographical range; second-order selection, home range of an individual or social group; third-order selection, use of various habitat components within the home range; and fourth-order selection, actual procurement of food types within the home range. Habitat selection categories may be discrete (e.g., open field, forest, rock outcropping) or continuous (e.g., shrub density, percentage cover, distance to water, canopy height; Manly et al. 2002), and when animals are not selective, they avoid or use resources in proportion to their availability (Alldredge et al. 1998, Katnik and Wielgus 2005).

Winter habitat use of white-tailed deer (*Odocoileus virginianus*; hereafter deer) has been studied across the northern regions of their distribution (Swenson et al. 1983, Mooty et al. 1987, Dusek et al. 1988, Gould and Jenkins 1983, Pauley et al. 1993). In response to severe winter conditions, deer conserve energy by seeking suitable habitat to reduce heat loss (Verme 1965) and by restricting movement (Moen 1978). However, each habitat type may not contain an adequate mixture of factors necessary for survival (i.e., forage quality and availability, shelter, protection from potential predators; Orians and Wittenberger 1991, Godvik et al. 2009). Animals experience increased energetic demands and susceptibility to predation while foraging in exposed habitats compared to sheltered areas (Mysterud and Ims 1998, Godvik et al. 2009). Deer have adapted to agriculturally dominated landscapes where food is abundant and permanent cover is scarce (Gladfelter 1984, Nixon et al. 2001). However, deer in agricultural regions may be more affected during winter by limited forested cover than in other regions (Gladfelter 1984).

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In the Northern Great Plains, it is common for a percentage of corn (*Zea mays*) to be left unharvested in December and remain until January–February because of environmental conditions (ranging from 1 to 35%; 5% 5-year average in South Dakota; South Dakota Department of Agriculture 2009, United States Department of Agriculture 2009*a*, *b*). To our knowledge, relative importance of standing corn as winter cover habitat and the subsequent selection and use of standing corn has not previously been documented. Thus, the purpose of our study was to document use of late season standing corn by female deer on winter range during a relatively mild winter in north-central South Dakota. Given limited availability of forested habitat in this region of the Northern Great Plains (Smith et al. 2002), we hypothesized that female deer would select standing corn as an alternative cover habitat.

STUDY AREA

Our study was conducted within the Northwestern Glaciated Plains and the Northern Glaciated Plains ecoregions (Bryce et al. 1998) in Edmunds (45°40' N, 99°20' W) and Faulk (45°07' N, 99°15' W) counties, north-central South Dakota during winter 2005–2006. Terrain was flat to gently rolling, intermixed with numerous pothole wetlands between mounds of glacial till (Bryce et al. 1998). We selected our study site because it serves as traditional winter range for a high density population of deer (25–51 deer/km^2; T. W. Grovenburg, South Dakota State University, unpublished data).

The Northern Glaciated Plains ecoregion was typified by a continental climate with extremes of hot and cold ambient temperatures (Kernohan 1994). Winter conditions ranged from mild, with little to no snow cover and above freezing temperatures, to severe, with complete snow cover and subzero temperatures for more than a month at a time (Petersen 1984). Mean daily winter temperatures ranged from –22 to 22° C (South Dakota Office of Climatology 2009). The region contained limited forested habitat (2.7%) and was dominated by agricultural activities with cultivated land (approximately equal hectares corn, soybeans [*Glycine max*], and wheat [*Triticum aestivum*]) and pasture/grassland constituting 42.4 and 44.6%, respectively, of total land use (Smith et al. 2002, United States Department of Agriculture 2009*a*). The study area had 14,975 ha of grasslands (erodible lands taken out of production and established with perennial cover) enrolled in the 2005 Conservation Reserve Program (CRP; United States Department of Agriculture 2009*a*). In 2005, corn harvest was 95% complete on 14 November (United States Department of Agriculture 2009*a*), halted prior to 1 December, and did not resume until April, after data collection was terminated.

METHODS

From January to April 2005 and January 2006, we captured adult female deer using modified clover traps (Clover 1956) and helicopter net guns (Barrett et al. 1982, Jacques et al. 2009). Additionally, we captured deer using immobilizing drugs (4.4 mg/kg Telezol and 2.2 mg/kg Xylazine) delivered via a pneu-dart (Pneu-Dart, Inc., Williamsport, PA, USA) with flight stabilizers from a Dan-Inject CO_2 Rifle, model JM Standard (Dan-Inject of North America, Ft. Collins, CO, USA; Haulton et al. 2001). We fitted each deer with a radiocollar (Advanced Telemetry Systems, Isanti, MN, USA) equipped with a mortality sensor. All methods used in this research were approved by the Institutional Animal Care and Use Committee at South Dakota State University (Approval number 04-A009).

We monitored radiocollared female deer 2–3 times per week through winter 2005–2006 (December–March) using ground triangulation with a null-peak antenna system (Brinkman et al. 2002). We gathered an equal number of diurnal and nocturnal locations to minimize temporal biases in home range analyses and eliminated locations if the error polygon overlapped >1 habitat type. We used LOCATE III (Nams 2006) to estimate locations using a minimum of three azimuths for all deer locations. We excluded locations with 95% error ellipses ≥20 ha from seasonal movement and home range analyses (Brinkman et al. 2005). To maintain temporal independence of observations for home range estimates (McNay et al. 1994), we did not track animals on successive days or at successive times during the day. We imported location estimates into ArcView (ESRI, Inc., Redlands, CA, USA) and used the fixed kernel method within Home Range Extension (HRE) of ArcView (Rodgers and Carr 1998) to calculate 95% home ranges during winter (December–February). We mapped all habitats encompassing the composite winter home range (95% composite home range based on locations of all females combined) of female deer using USGS 3-m Digital Orthophoto Quadrangles to determine population level availability. We used 95% home ranges to determine percentage of each habitat type available at the home range level (Table 1). For resource selection analyses, habitat categories included forested, standing corn, harvested crops, alfalfa (*Medicago sativa*)/grassland/pasture, water, wetlands, CRP, and roads/development.

We calculated resource selection using design II and III analyses (Manly et al. 2002) to determine whether selection was positive, negative, or neutral for habitat categories. We used Program R version 2.8.1 (R Development Core Team 2009) with the adehabitat library (Calenge 2006) to calculate selection ratios and chi-square tests for overall deviation from random use of habitat types. We defined use as an animal location in a particular habitat and availability as percent of each habitat available at the population (design II; composite home range) and individual levels (design III; individual home range). Selection ratios were calculated as use/availability, and selection at the population level was determined by averaging individual selection ratios (Manly et al. 2002). With design II analysis, we sampled data on selection of resource units by individual animals using population level resource availability. Design III measured the use and availability of resource units separately for each female deer (Manly et al. 2002). Cover type selection for both design II and III analyses was indicated if the selection ratio ($\hat{w}$) differed significantly from 1. For instance, selection for a habitat category was indicated if the confidence interval for w_i did not contain the value 1 and the lower limit was >1. A habitat category was avoided if the confidence interval for w_i did not contain the value 1 and the upper limit was <1. Use in proportion to availability was indicated if the confidence interval for w_i contained the value 1 (Manly et al. 2002). We used eigenanalysis of selection ratios to explain variation in cover type selection among animals (Calenge and Dufour 2006). If all animals selected the same habitat types, then use of the first axis of analysis explained most variation in cover type selection. However, when variability existed in cover type selection, eigenanalysis generated several axes according to selection (Calenge and Dufour 2006).

Table 1. Cover types available and number of locations in each cover type for adult female white-tailed deer in north-central South Dakota, winter 2005–2006.

Habitat	Available (%)	Use (%)
Standing corn	4.8	169 (19.5)
Forested	1.9	47 (5.4)
CRP	5.7	91 (10.5)
Wetland	1.0	16 (1.8)
Harvested crops	52.3	252 (29.0)
Grassland[a]	29.7	277 (31.9)
Water	0.5	3 (0.3)
Roads[b]	4.1	13 (1.5)

[a]Grassland includes grassland, alfalfa, and pasture; [b]Roads includes roads and development.

We used logistic regression (Mysterud and Ims 1998) to test for functional response in habitat use (i.e., a change in relative use with changing availability). To test whether deer were substituting standing corn for traditional deer cover habitats, we compared effects of forested cover, CRP, wetlands, and standing corn on deer selection. With an appropriately fitted model ($P > 0.05$), an estimated slope (β) parameter $\neq 1$ indicated functional response, and a slope equal to 0 indicated a consistent use of habitat as availability changed. Random use of habitat was indicated by α (intercept) = 0 and $\beta = 1$ (Mysterud and Ims 1998); if $\alpha > 0$ and $\beta \geq 1$, the habitat tested was always selected (i.e., disproportionate use compared to availability). For other combinations of intercept and slope values, cover type selection was inferred when the lower limit of the 95% confidence interval for the fitted proportion of the habitat used exceeded proportional availability of that habitat (Mysterud and Ims 1998).

RESULTS

During winter 2005–2006, we collected 868 winter locations (Table 1) from 30 female white-tailed deer. Patches of unharvested corn ($n = 7$) were similar in size ($t_6 = 0.53$, $P = 0.62$, range 52.6–64.7 ha); therefore, we were unable to detect a correlation between patch size and use. Mean number of locations used to calculate individual winter home ranges was 28.9 (SE = 1.6, range 24–38). At the population level (design II), female deer did not randomly select habitat in proportion to availability ($\chi^2_{210} = 1139.94$, $P < 0.001$) and selection was not identical for all animals ($\chi^2_{203} = 704.45$, $P < 0.001$). Deer selected standing corn and CRP habitats greater than expected by chance and deer avoided harvested crops and development (Table 2, Fig. 1). Eigenanalysis of selection ratios produced 2 factors that explained 88.7% (55.8%, first axis; 32.9%, second axis) of the variability in individual animal cover type selection; selection for standing corn explained 55.8% of the variability in cover type selection.

At the 95% home range level (design III), deer did not randomly select habitat in proportion to availability ($\chi^2_{106} = 168.3$, $P < 0.001$). Deer selected standing corn and CRP habitats greater than expected by chance and avoided harvested crops, water, and development (Table 2, Fig. 2). Eigenanalysis of selection ratios produced 2 factors that explained approximately 64.8% of the variability in individual animal winter cover type selection; information explained was similar for the 2 axes (34.1% for the first axis, and 30.7% for the second). Addition of a third factor increased information explained to 87.2%; selection for standing corn and CRP explained 64.8% of the variability in cover type selection.

Analysis of functional assessment for standing corn ($G_{22} = 32.04$, $P = 0.08$; Table 3, Fig. 3a) indicated good model fit to the data. Confidence interval estimates for β (Table 3) indicated $\beta > 1$; thus, deer used standing corn disproportionately compared to availability (Fig. 3a). Analysis of functional assessment for forested habitat provided adequate model fit to the data ($G_{28} = 34.31$, $P = 0.19$; Table 3, Fig. 3b). Confidence interval estimates for β (Table 3) indicated the estimated value of the slope parameter (β) was zero; thus, deer used forested habitat consistently as availability of forested habitat increased (Fig. 3b). To address the issue of high leverage of a single outlier in the forested habitat assessment, we removed the animal with 17.1% (Fig. 3b) proportion of standing corn available and reanalyzed the data. Results (G_{27} = 32.73, P = 0.21) indicated good model fit and confidence interval estimates for the slope parameter (0.73, −0.20–1.66) indicated β = 0. Thus, predictive capabilities of our original forested habitat functional assessment model were adequate. Functional assessment results for CRP (G_{28} = 36.10, P = 0.14) indicated good model fit (Table 3, Fig. 3c). Confidence interval estimates for β (Table 3) indicated β > 1; thus, deer used CRP habitat more than expected compared to availability (Fig. 3c). Also, analysis of functional assessment for wetland habitat (G_{28} = 11.36, P = 0.99) indicated good model fit to our data (Fig. 3d). Confidence interval estimates for β (Table 3) indicated that β = 1; thus, deer proportionately used wetland habitat as availability increased (Fig. 3d).

Table 2. Estimated selection ratios, standard error, and confidence intervals of selection for winter habitat of white-tailed deer (n = 30) in north-central South Dakota during the winter of 2005–2006 using design II and III (Manly et al. 2002) with known proportions of available resource units.

Habitat	Design II				Design III			
	Selection index	SE	CI		Selection index	SE	CI	
	($\hat{w}$)		Lower	Upper	($\hat{w}$)		Lower	Upper
Forested	1.89	0.55	0.514	3.266	1.19	0.22	0.628	1.743
Standing corn	4.31$^+$	0.85	2.194	6.433	1.35$^+$	0.10	1.094	1.600
Harvested crops	0.55$^-$	0.05	0.436	0.669	0.73$^-$	0.06	0.573	0.883
Alfalfa/Pasture	1.07	0.12	0.760	1.374	1.11	0.10	0.845	1.367
Water	0.75	0.41	0.000[a]	1.774	0.38$^-$	0.18	0.000[a]	0.835
Wetlands	1.70	0.61	0.175	3.229	1.31	0.27	0.628	1.983
CRP	2.81$^+$	0.38	1.847	3.763	1.44$^+$	0.17	1.008	1.872
Development	0.37$^-$	0.12	0.053	0.677	0.55$^-$	0.16	0.145	0.953

[a]For water a negative lower limit was changed to 0.000. Limits for this habitat were unreliable because of the low sample count of used resources; $^+$Indicates that the selection coefficient $\hat{w}$ is significantly different from 1 and the habitat is used more than expected; $^-$Indicates that the selection coefficient $\hat{w}$ is significantly different from 1 and the habitat is used less than expected.

DISCUSSION

Deer in the Glaciated Plains region of the Northern Great Plains showed stronger selection for late season standing corn than for traditional winter cover habitats (i.e., forested, wetland). Winter cover is important to deer (Mooty et al. 1987, Parker and Gillingham 1990) in northern regions and standing corn provided cover and forage that may have enabled animals to maintain body core temperatures and subsequently minimize thermoregulatory costs (Hanley et al. 1989, DePerno et al. 2003). Additionally, standing corn likely provided deer with readily available forage, thereby minimizing possible risk of predation from coyotes (*Canis latrans*).

Interestingly, we documented winter selection for CRP habitat, which may have been related to mild winter temperatures. Deer winter severity index for winter 2005–2006 indicated a very mild winter (DWSI = 36) and mean monthly temperatures for December–February were warmer than the 30-year average (Grovenburg et al. 2009). Gould and Jenkins (1993) documented selection for CRP during spring/early summer and proportional use of CRP fields in east-central South Dakota during a winter with similar mild temperatures (South Dakota Office of Climatology 2009). In many regions of the Northern Great Plains, forested cover is limited and fragmented (Smith et al. 2002), leading deer to seek out substitute cover habitat. Minimal snow cover and mild winter temperatures throughout north-central South Dakota may have contributed to increased use of CRP habitat, allowing deer access to CRP grasslands without energy expenditure associated with movement through heavy snow (Parker et al. 1984, Robbins 2001) or heat loss due to temperature ≤−7° C (DelGiudice 2000).

Table 3. Test for goodness-of-fit and parameter estimates (point estimates and 95% confidence limits) for the logistic regression equation logit (proportion used) = α + β logit (proportion available) for the data from white-tailed deer (n = 30) in north-central South Dakota during winter 2005–2006.

				Intercept			Slope		
Habitat	Residual G[a]	P[a]	Residual G/df	α	95% CL		β	95% CL	
Corn	32.04	0.077	1.46	1.15	0.68	1.63	1.58	1.24	1.94
Forested	34.31	0.191	1.23	−1.96	−3.72	−0.20	0.29	−0.27	0.85
CRP	36.10	0.140	1.29	1.34	0.80	1.89	1.43	1.17	1.69
Wetland	11.36	0.998	0.41	2.00	0.00	4.13	1.50	0.94	2.18

[a]Goodness-of-fit statistics are residual deviance (G) and P value for the model (P values < 0.05 indicate that models fit the data poorly; Mysterud and Ims 1998).

Land enrolled in the CRP peaked at 14.9 million ha in September 2007 and by October 2007, CRP enrollment had declined by 931,000 ha, of which 850,000 ha were grasslands (Fargione et al. 2009, United States Department of Agriculture 2009*c*). As of spring 2009, CRP enrollment was 13.6 million ha with an additional 1.8 million due to expire on 30 September 2009 (United States Department of Agriculture 2009*b*). Several factors contributed to a decline in enrolled hectares (United States Department of Agriculture 2007, Fargione et al. 2009). First, the Food, Conservation, and Energy Act of 2008 mandated a reduced total of allowable hectares that may be enrolled in the CRP to 12.9 million ha by 2010. The United States Department of Agriculture projects that CRP enrolled land reach a historical low of 12.2 million ha in 2013 (Fargione et al. 2009, United States Department of Agriculture 2009*c*). Second, increased demand for biofuel production has large land-use implications; greater demand for biofuels has caused and may continue to cause idle croplands to revert back into crop production (Secchi and Babcock 2007, Searchinger et al. 2008, Fargione et al. 2009). Demand for agricultural land to grow corn for biofuels increased by 4.9 million ha between 2005 and 2008 in the United States, with potentially wide-ranging effects on wildlife due to loss of habitat (Fargione et al. 2009). Current United States law mandates production of 136 billion liters of biofuel by 2022, a 740% increase over 2006 production levels (Fargione et al. 2009). Continued losses of CRP in the Northern Great Plains will depress the already limited cover available to deer, contribute to even greater fragmentation of habitats, and potentially lead to changes in deer behavior and survival.

Importance of winter shelter to deer has been well documented (Gould and Jenkins 1993, DePerno et al. 2003, Klaver et al. 2008), yet limited use of forested habitat was documented during our study. Typically, deer use forested habitat during winter for thermal protection to minimize energy expenditure, even though availability of forage in this habitat is limited (Verme 1965, Dusek 1980, Swenson et al. 1983). Researchers have documented that distributions of deer in the Northern Great Plains were dependent on forested habitats (Sparrowe and Springer 1970). In areas where snow depth is commonly >40 cm, habitat that provides thermal cover, such as mature second growth forests and wetland vegetation, is necessary (Pauley et al. 1993). During our study, several factors might explain the lack of use of forested habitat. First, snow depth never exceeded 12.7 cm (South Dakota Office of Climatology 2009) and was considerably below snow depth necessary to restrict deer movements (40.0 cm; Kelsall 1969). Movement through deep snow is metabolically expensive because deer must expend energy to elevate the body repeatedly (Parker et al. 1984, Robbins 2001). DelGiudice (2000) documented that heat loss may exceed energy expenditure for standard metabolism and activity at temperatures ≤−7° C. Second, only 21% of mean daily temperatures reached or exceeded this threshold (South Dakota Office of Climatology 2009). Mild temperatures and minimal snow cover may have contributed to relatively unrestricted deer movements throughout winter home ranges, thereby minimizing use of forested cover. Third, this area of the Northern Great Plains has limited, fragmented patches of forested habitat (Smith et al. 2002). Consequently, deer may have adjusted their daily activities and home ranges to locate and subsequently utilize alternative cover habitats.

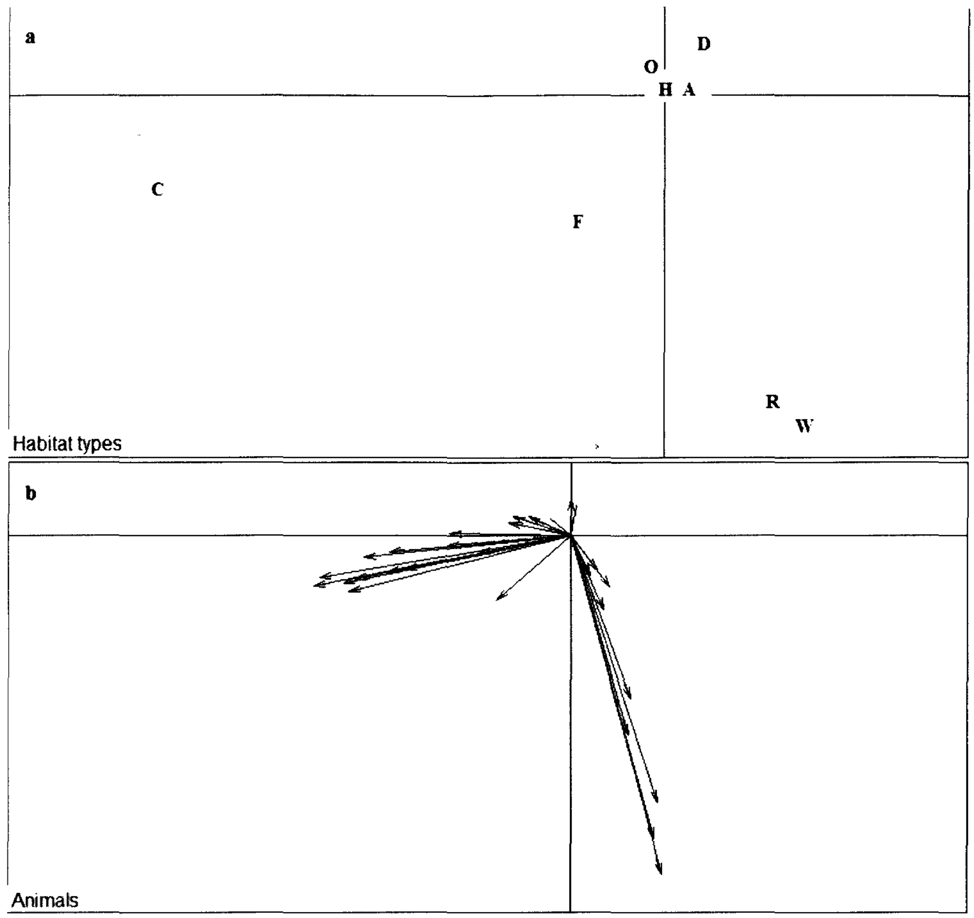

Figure 1. Results of the eigenanalysis (Calenge and Dufour 2006) of population level (design II; Manly et al. 2002) selection ratios conducted to determine winter habitat selection by 30 adult female white-tailed deer on eight habitat variables in north-central South Dakota, USA, 2005–2006. (a) Habitat type loadings on the first 2 factorial axes. (b) Animal scores on the first factorial plane. Vectors represent individual white-tailed deer. C = late season standing corn, F = forested, O = water, H = harvested crops, A = alfalfa/pasture/grassland, D = development, R = Conservation Reserve Program, W = wetland, horizontal axis = first factorial axis, vertical axis = second factorial axis.

Our results contradict the close association between deer and wetland habitat previously documented throughout the Northern Great Plains (Peterson 1984, Dusek et al. 1988, Naugle et al. 1997). Smith and Flake (1983) documented the importance of wetland habitats associated with rivers and streams to deer in the Northern Great Plains and Compton et al. (1988) concluded that riparian cover was a primary factor influencing local density and distribution of deer along the lower Yellowstone River. Additionally, Sparrowe and Springer (1970) reported that deer movement in this region of the Northern Great Plains typically follows riparian systems. Naugle et al. (1997) observed decreased use of wetlands for escape cover during one year of their study; this was attributed to unusually high water levels. Limited available wetland habitat at population and home range levels may have influenced deer activity. Furthermore, wetland habitat in our study area was fragmented and individual wetlands were relatively small in size (<1.6 ha average), thereby limiting their potential as suitable deer winter habitat.

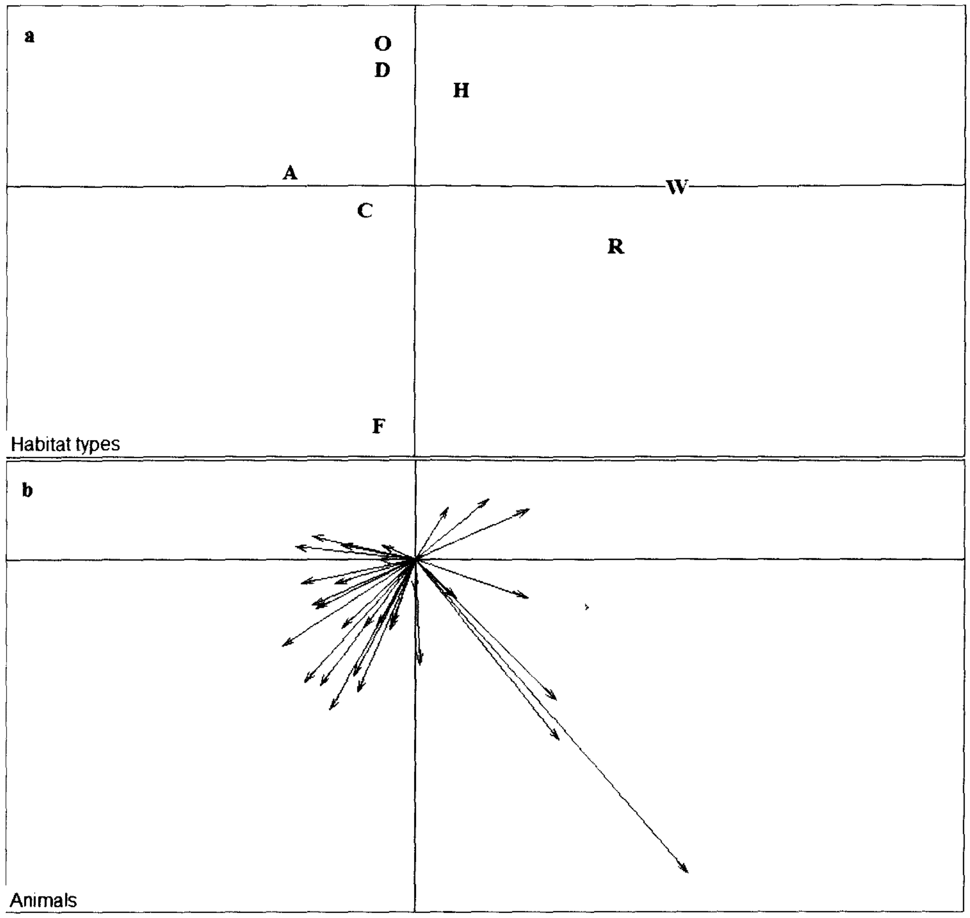

Figure 2. Results of the eigenanalysis (Calenge and Dufour 2006) of home range level (design III; Manly et al. 2002) selection ratios conducted to highlight winter habitat selection by 30 adult female white-tailed deer on eight habitat variables in north-central South Dakota, USA, 2005–2006. (a) Habitat type loadings on the first 2 factorial axes. (b) Animal scores on the first factorial plane. Vectors represent individual white-tailed deer. C = late season standing corn, F = forested, O = water, H = harvested crops, A = alfalfa/pasture/grassland, D = development, R = Conservation Reserve Program, W = wetland, horizontal axis = first factorial axis, vertical axis = second factorial axis.

Variability in cover type selection highlighted by eigenanalysis can be explained, in part, by structure and distribution of patches of suitable habitat on the landscape. We believe that patches of suitable habitat were too distant to allow deer to use all habitat types. Our results supported conclusions by Swenson et al. (1983), who noted that deer exhibited variation in wintering strategy based upon forage and cover resources available within home ranges. Selection of specific habitats varied substantially between individual animals. In deer concentration areas, habitat diversity is necessary to meet winter requirements for survival (Armstrong et al. 1983).

Our results indicated a trade-off in deer cover type selection and were directly related to changes in availability of standing corn and CRP habitat. We demonstrated that selection of late season standing corn and CRP increased with availability, while selection of forested habitat remained consistent regardless of availability. Mild winter weather likely influenced selection for CRP habitat, providing deer with concealment (bedding) cover and facilitating daily activities normally not available during more severe winters. Thus, CRP habitat may provide a critical habitat component to deer in intensively farmed regions throughout the Midwest (Higgins et al. 1987). However, severe winters might lead to avoidance of CRP habitat and subsequent increased use of forested or wetland habitat by deer.

We hypothesize that deer in this region replaced traditional winter cover (forested habitat) and forage (harvested agricultural row crops) habitats by maximizing use of late season standing corn. During our study, distribution of animals was strongly influenced by composition and spatial distribution of resources (Roseberry and Woolf 1998), and varied with landscape-level availability (Godvik et al. 2009). Standing corn represented ideal wintering habitat for deer in a prairie ecosystem

(Sparrowe and Springer 1970, Petersen 1984, Kernohan 1994). Additionally, we hypothesize that selection and functional response for late season standing corn habitat would increase during severe winters. However, variability in weather and corn harvest completion may potentially limit availability of this habitat to deer in this region.

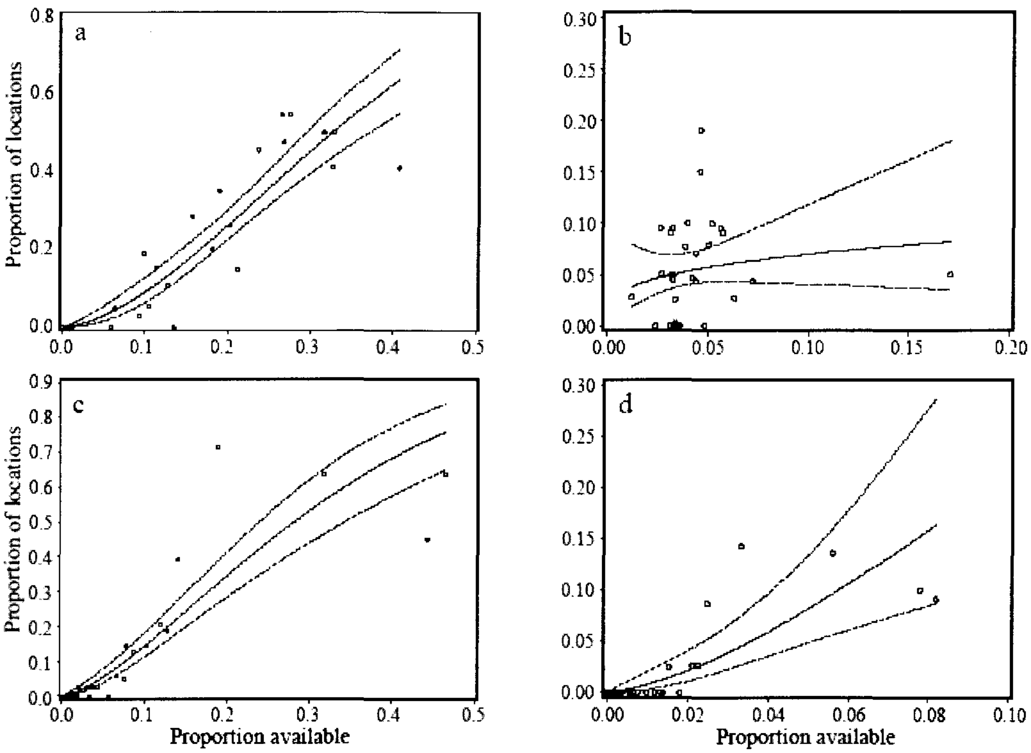

Figure 3. Logistic regression analyses of proportional use against proportion of that habitat available within individual white-tailed deer winter home ranges with 95% confidence envelopes in north-central South Dakota, USA, 2005–2006. (a) late season standing corn habitat, (b) forested habitat, (c) CRP habitat, and (d) wetland habitat.

MANAGEMENT IMPLICATIONS

Due to limited availability and fragmentation of winter habitats in the Glaciated Plains region of the Northern Great Plains, loss of cover and forage habitat (i.e., CRP and late season standing corn habitat) through anthropogenic disturbance could result in reduced availability of thermal cover and winter forage, and ultimately increase winter mortality of deer throughout the Northern Great Plains. We recognize that our study occurred during relatively mild winter conditions and that use of late season corn habitats may vary temporally and with increasing winter severity; during severe winter weather, forested cover may be selected with greater frequency. Thus, quantitative information on deer use of late season corn during severe winter conditions is warranted and may help to elucidate potential effects of intrinsic and extrinsic factors on resource selection by deer in the Northern Great Plains. Selection during severe winter would help determine if deer are choosing between cover and forage, or if standing corn satisfies both requirements. This information would facilitate direct comparisons of deer habitat use associated with effects of temporal changes in environmental conditions and habitat quality throughout the Northern Great Plains. If standing corn satisfies both requirements, knowledge of average unharvested corn acreage would provide managers with empirical data for population management.

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LITERATURE CITED

Alldredge, J. R., D. L. Thomas, and L. L. McDonald. 1998. Survey and comparison of methods for study of resource selection. Journal of Agricultural, Biological, and Environmental Statistics 3:237–253.

Armstrong, E., D. Euler, and G. Racey. 1983. White-tailed deer habitat and cottage development in central Ohio. Journal of Wildlife Management 47:605–612.

Arthur, S. M., B. F. J. Manly, L. L. McDonald, and G. W. Garner. 1996. Assessing habitat selection when availability changes. Ecology 77:215–227.

Barrett, M. W., J. W. Nolan, and L. D. Roy. 1982. Evaluation of hand-held net-gun to capture large mammals. Wildlife Society Bulletin 10:108–114.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, J. D. Erb, and B. S. Haroldson. 2002. A vehicle-mounted radiotelemetry antenna system design. Wildlife Society Bulletin 30:258–262.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, B. S. Haroldson, and R. G. Osborn. 2005. Movement of female white-tailed deer: effects of climate and intensive row-crop agriculture. Journal of Wildlife Management 69:1099–1111.

Bryce, S., J. M. Omernik, D. E. Pater, M. Ulmer, J. Schaar, J. Freeouf, R. Johnson, P. Kuck, and S. H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. Jamestown, North Dakota: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/1998/ndsdeco/ndsdeco.htm>. Accessed 12 August 2005.

Calenge, C. 2006. The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197:516–519.

Calenge, C., and A. B. Dufour. 2006. Eigenanalysis of selection ratios from animal radio-tracking data. Ecology 87:2349–2355.

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

Compton, B. B., R. J. Mackie, and G. L. Dusek. 1988. Factors influencing distribution of white-tailed deer in riparian habitats. Journal of Wildlife Management 52:544–548.

Cooper, A. B., and J. J. Millspaugh. 2001. Accounting for variation in resource availability and animal behavior in resource selection studies. Pages 243–273 *in* J. J. Millspaugh and J. M. Marzluff, editors. Radio tracking and animal populations. Academic Press, San Diego, California, USA.

DelGiudice, G. D. 2000. Assessing the relationship of conifer thermal cover to winter distribution, movements, and survival of white-tailed deer in north central Minnesota. Pages 35–51 *in* M. W. DonCarlos, R. T. Eberhardt, R. O. Kimmel, and M. S. Lenarz, editors. Summaries of wildlife research findings, 2000. Section of Wildlife, Department of Natural Resources, St. Paul, Minnesota, USA.

DePerno, C. S., J. A. Jenks, and S. L. Griffin. 2003. Multidimensional cover characteristics: is variation in habitat selection related to white-tailed deer sexual segregation. Journal of Mammalogy 84:1316–1329.

Dusek, G. L. 1980. An inventory of vegetation, wildlife and recreational resources of the Long Pines, Montana. Unpublished report, Montana Department of Fish, Wildlife and Parks, Helena, USA.

Dusek, G. L., A. K. Wood, and R. J. Mackie. 1988. Habitat use by white-tailed deer in prairie-agricultural habitat in Montana. The Prairie Naturalist 20:135–142.

Fargione, J. E., T. R. Cooper, D. J. Flaspohler, J. Hill, C. Lehman, T. McCoy, S. McLeod, E. J. Nelson, K. S. Oberhauser, and D. Tilman. 2009. Bioenergy and wildlife: threats and opportunities for grassland conservation. Bioscience 59:767–777.

Franklin, A. B., D. R. Anderson, R. J. Gutierrez, and K. P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs 70:539–590.

Gillies, C. S., M. Hebblewhite, S. E. Nielsen, M. E. Krawchuk, C. L. Aldridge, J. L. Frair, D. J. Saher, C. E. Stevens, and C. L. Jerde. 2006. Application of random effects to the study of resource selection by animals. Ecology 75:887–898.

Gladfelter, H. L. 1984. Midwest agricultural region. Pages 427–440 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Godvik, I. M. R., L. E. Loe, J. O. Vik, V. Veiberg, R. Landvatn, and A. Mysterud. 2009. Temporal scales, trade-offs, and functional responses in red deer habitat selection. Ecology 90:699–710.

Gould, J. H., and K. J. Jenkins. 1993. Seasonal use of Conservation Reserve Program lands by white-tailed deer in east-central South Dakota. Wildlife Society Bulletin 21:250–255.

Grovenburg, T. W., J. A. Jenks, R. W. Klaver, C. C. Swanson, C. N. Jacques, and D. Todey. 2009. Seasonal movements and home ranges of white-tailed deer in north-central South Dakota. Canadian Journal of Zoology 87:876–885.

Hanley, T. A., C. T. Robbins, and D. E. Spalinger. 1989. Forest habitats and the nutritional ecology of sitka black-tailed deer: a research synthesis with implications for forest management. United States Department of Agriculture, Forest Service, General Technical Report PNW-GTR-230, Portland, Oregon, USA.

Haulton, S. M., W. F. Porter, and B. A. Rudolph. 2001. Evaluating 4 methods to capture white-tailed deer. Wildlife Society Bulletin 29:255–264.

Higgins, K. F., D. E. Nomsen, and W. A. Wentz. 1987. The role of the Conservation Reserve Program in relation to wildlife enhancement, wetlands and adjacent habitats in the Great Plains. Pages 99–104 *in* J. E. Mitchell, editor. Impacts of the Conservation Reserve Program in the Great Plains. U.S. Forest Service General Technical Report RM-158.

Jacques, C. N., J. A. Jenks, C. S. DePerno, J. D. Sievers, T. W. Grovenburg, T. J. Brinkman, C. C. Swanson, and B. A. Stillings. 2009. Evaluating ungulate mortality associated with helicopter net gun captures in the Northern Great Plains. Journal of Wildlife Management 73:1282–1291.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Katnik, D. D., and R. B. Wielgus. 2005. Landscape proportions versus Monte Carlo simulated home ranges for estimating habitat availability. Journal of Wildlife Management 69:20–32.

Kelsall, J. P. 1969. Structural adaptations of moose and deer for snow. Journal of Mammalogy 50:302–310.

Kernohan, B. J. 1994. Winter/spring population characteristics of white-tailed deer in an agricultural/wetland complex in northeastern South Dakota. Thesis. South Dakota State University, Brookings, USA.

Klaver, R. W., J. A. Jenks, C. S. DePerno, and S. L. Griffin. 2008. Associating seasonal range characteristics with survival of female white-tailed deer. Journal of Wildlife Management 72:343–353.

Lubin, Y., S. Ellner, and M. Kotzman. 1993. Web relocation and habitat selection in a desert widow spider. Ecology 74:1915–1928.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Second edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.

McNay, R. S., J. A. Morgan, and F. L. Bunell. 1994. Characterizing independence of observations in movement of Columbian white-tailed deer. Journal of Wildlife Management 58:422–429.

Moen, A. N. 1978. Seasonal changes in heart rates, activity, metabolism, and forage intake of white-tailed deer. Journal of Wildlife Management 42:715–738.

Mooty, J. J., P. D. Karns, and T. K. Fuller. 1987. Habitat use and seasonal range size of white-tailed deer in northcentral Minnesota. Journal of Wildlife Management 51:644–648.

Mysterud, A., and R. A. Ims. 1998. Functional responses in habitat use: availability influences relative use in trade-off situations. Ecology 79:1435–1441.

Nams, V. O. 2006. Locate III User's Guide. Pacer Computer Software, Tatamagouche, Nova Scotia, Canada.

Naugle, D. E., J. A. Jenks, B. J. Kernohan, and R. R. Johnson. 1997. Effects of hunting and loss of escape cover on movements and activity of female white-tailed deer, *Odocoileus virginianus*. Canadian Field-Naturalist 111:595–600.

Nixon, C. M., L. P. Hansen, P. A. Brewer, J. E. Chelsvig, T. L. Esker, D. Etter, J. B. Sullivan, R. G. Koerkenmeier, and P. C. Mankin. 2001. Survival of white-tailed deer in intensively farmed areas of Illinois. Canadian Journal of Zoology 79:581–588.

Orians, G. H., and J. F. Wittenberger. 1991. Spatial and temporal scales in habitat selection. The American Naturalist 137:29–49.

Parker, K. L., and M. P. Gillingham. 1990. Estimates of critical thermal environments for mule deer. Journal of Range Management 43:73–80.

Parker, K. L., C. T. Robbins, and T. A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management 48:474–48

Pauley, G. R., J. M. Peek, and P. Zager. 1993. Predicting white-tailed deer habitat use in northern Idaho. Journal of Wildlife Management 57:904–913.

Petersen, L. E. 1984. Northern Plains. Pages 441–448 *in* L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

R Development Core Team. 2009. R: A Language and Environment for Statistical Computing. R

Foundation for Statistical Computing, Vienna, Austria.

Robbins, C. T. 2001. Wildlife feeding and nutrition. Academic Press, Inc., San Diego, California, USA.

Rodgers, A. R., and A. P. Carr. 1998. HRE: The home range extension for ArcView. Centre for Northern Forest Ecosystem Research, Ontario Ministry of Natural Resources, Ontario, Canada.

Roseberry, J. L., and A. Woolf. 1998. Habitat-population density relationships for white-tailed deer in Illinois. Wildlife Society Bulletin 26:252–258.

Searchinger, T., R. Heimlich, R. A. Houghton, F. X. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, and T. H. Yu. 2008. Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 319:1238–1240.

Secchi, S., and B. A. Babcock. 2007. Impact of high corn prices on Conservation Reserve Program acreage. Iowa Ag Review 13:4–7.

Smith, R. L., and L. D. Flake. 1983. The effects of grazing on forest regeneration along a prairie river. The Prairie Naturalist 15:41–44.

Smith, V. J., J. A. Jenks, C. R. Berry, Jr., C. J. Kopplin, and D. M. Fecske. 2002. The South Dakota Gap Analysis Project. Final Report. Research Work Order No. 65. Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, USA.

South Dakota Department of Agriculture. 2009. <http://www.state.sd.us/doa>. Accessed 2 April 2009.

South Dakota Office of Climatology. 2009. South Dakota climate and weather. <http://climate.sdstate.edu>. Accessed 2 April 2009.

Sparrowe, R. D., and P. F. Springer. 1970. Seasonal activity patterns of white-tailed deer in eastern South Dakota. Journal of Wildlife Management 34:420–431.

Swenson, J. E., S. J. Knapp, and H. J. Wentland. 1983. Winter distribution and habitat use by mule deer and white-tailed deer in southeastern Montana. The Prairie Naturalist 15:97–112.

United States Department of Agriculture. 2007. Conservation Reserve Program Monthly Summary October 2007. United States Department of Agriculture, Washington, DC, USA.

United States Department of Agriculture. 2009*a*. National Agricultural Statistics Service. <http://www.nass.usda.gov/sd>. Accessed 2 April 2009.

United States Department of Agriculture. 2009*b*. Farm Service Agency. <http://www.fsa.usda.gov/fsa>. Accessed 2 April 2009.

United States Department of Agriculture. 2009*c*. USDA Long-Term Agricultural Projection Tables.<http://www.usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://www.usda.mannlib.cornell.edu/usda/ers/94005/./2009/index.html>. Accessed 23 November 2009.

Verme, L. J. 1965. Swamp conifer deeryards in northern Michigan: their ecology and management. Journal of Forestry 63:523–529.

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