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Management and Conservation

Spatial Ecology of White-Tailed Deer Fawns in the Northern Great Plains: Implications of Loss of Conservation Reserve Program Grasslands

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ABSTRACT Few studies have evaluated how wildlife, and white-tailed deer (*Odocoileus virginianus*) in particular, respond to Conservation Reserve Program (CRP) grasslands. We conducted a 3-year study (2007–2009) to determine the influence of CRP on fawn ecology during a time of declining CRP enrollment. We captured and radiocollared 81 fawn white-tailed deer during 15 May to 15 June 2007–2009 in north-central South Dakota, collected 6,505 locations, and documented 70 summer home ranges. Mean summer home ranges increased temporally during 2007–2009 ($P < 0.001$) and corresponded to a 41% loss of CRP grasslands in the area (2.3% loss in land cover and approx. 21% loss in cover habitat in the study area) over the duration of the study. Additionally, mean movement between daily locations increased ($P < 0.001$) from 2007 to 2009. Analysis of covariance models indicated that change in CRP influenced home-range size, and change in CRP and wheat influenced daily movement. Smaller home ranges and reduced movements were associated with greater quantity of CRP available to fawns, and increased movements were associated with more acreage of wheat available to fawns. Fawns shifted resource selection during the summer at a mean age ranging from 48.8 days to 58.6 days, and this shift was associated with height of corn (83–87 cm). During early summer, fawns consistently selected for CRP; selection of wheat progressed temporally from avoidance in 2007 to selection in 2009. During late summer, fawns consistently selected for corn habitat and used CRP at least in proportion to its availability. Reduction in CRP-grasslands seemed to increase fawn home-range size and daily movements and, influenced change in resource selection to wheat. Current legislation mandates continued decrease in CRP enrollment and concomitant increase in the planting of corn for ethanol production. Management of habitat throughout the grasslands of the Northern Great Plains that maximizes cover habitats would provide neonates with adequate cover for protection from predators. © 2011 The Wildlife Society.

KEY WORDS Conservation Reserve Program, CRP, fawn, home range, movement, northern Great Plains, *Odocoileus virginianus*, resource selection, South Dakota, white-tailed deer.

Various land conservation programs have been implemented by the Federal Government of the United States to mitigate environmental impacts of agricultural production, with the most successful being the Conservation Reserve Program of the Food Security Act of 1985 (CRP; Riffell et al. 2008, Fargione et al. 2009). Supporting commodity prices, improving water quality on highly erodible croplands, and soil conservation were the original purposes of the CRP (Food

and Agricultural Policy Research Institute 2007, Fargione et al. 2009). The CRP is a voluntary program that pays annual rent to landowners who enroll their agricultural land and convert it to permanent cover such as perennial grasslands (Gray and Teels 2006, Fargione et al. 2009). CRP plantings are used by a variety of birds of conservation concern (Johnson 2005, Gray and Teels 2006), have increased densities of grassland birds (Niemuth et al. 2007), have contributed to 25.7 million additional ducks in the Prairie Pothole Region (Reynolds 2005, Gray and Teels 2006) through increased nest success (Reynolds et al. 2001), and have increased ring-necked pheasant (*Phasianus colchicus*) counts (Nielson et al. 2008).

Land enrolled in the CRP peaked at 14.9 million ha in September 2007; however, CRP enrollment declined by 931,000 ha by October 2007 (Fargione et al. 2009,

United States Department of Agriculture 2009). CRP enrollment as of spring 2009 was 13.6 million ha with an additional 1.8 million due to expire on 30 September 2009 (United States Department of Agriculture 2011). Furthermore, the United States Department of Agriculture predicted that CRP-enrolled land would reach a low of 12.2 million ha in 2013 (Fargione et al. 2009, United States Department of Agriculture 2009).

Several factors contributed to the decline in enrolled hectares (United States Department of Agriculture 2007, Fargione et al. 2009). First, the Food, Conservation, and Energy Act of 2008 reduced the total hectares enrollable in the CRP to 12.9 million by 2010. This legislation mandated a reduced total of allowable hectares with no established minimum enrolled hectares (Fargione et al. 2009, United States Department of Agriculture 2009). Second, increased demand for biofuel production has potentially large land-use implications; greater demand for biofuels has resulted in CRP lands returning to crop production (Secchi and Babcock 2007, Searchinger et al. 2008, 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). Approximately one-third of the nation's corn crop is now used for ethanol production and farmers have shifted land into corn production from other crops, idle agricultural land, and native prairie (Brooke et al. 2009). Between 2005 and 2007, an additional 1.7 million ha of land were converted into corn production in Iowa, Minnesota, North Dakota, and South Dakota (Brooke et al. 2009). In total, 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 this modification of habitat (Fargione et al. 2009).

Higgins et al. (1987) hypothesized that CRP-grasslands provided a missing habitat component in intensively managed agricultural areas with limited cover, potentially affecting wildlife species such as white-tailed deer (*Odocoileus virginianus*; hereafter deer). CRP fields were used by adult deer seasonally and diurnally for both bedding and active periods, with increased use corresponding to rapid vegetative growth in spring and early summer (Gould and Jenkins 1993). During a mild winter in the northern Great Plains, adult female deer selected for CRP-grasslands (Grovenburg et al. 2010b). Additionally, neonates in the northern Great Plains selected for bed sites in tall grass-CRP over other habitat types during their first 30 days of life; vertical structure provided thermal insulation, and cover and concealment from predators (Grovenburg et al. 2010a).

Fawn studies have been conducted across the species' distributional range documenting bed-site selection (Huegel et al. 1986, Grovenburg et al. 2010a), survival (Nelson and Woolf 1987, Brinkman et al. 2004a, Vreeland et al. 2004, Pusateri-Burroughs et al. 2006, Rohm et al. 2007, Grovenburg et al. 2011b), and home ranges (Carroll and Brown 1977, Garner and Morrison 1977, Ozoga et al. 1982, Pusateri-Burroughs

et al. 2006, Hiller et al. 2008). Because fawns are the life stage most vulnerable to mortality, obtaining empirical data on factors influencing their ecology is critical for population management (Porath 1980, Rohm et al. 2007). To our knowledge, however, the role of CRP grasslands in fawn ecology beyond bed site selection in the northern Great Plains is unknown.

Forested habitat (i.e., traditional cover) is limited and often fragmented in the northern Great Plains (Smith et al. 2002), which could affect fawn ecology. Therefore, our first objective was to document fawn home range use and daily movement in an area with limited permanent cover. Because adult deer in the region had large home ranges and movements (Grovenburg et al. 2009b), we theorized that fawn home-range size and movements would be larger than previously documented. Adult deer have been documented using CRP-grasslands seasonally for cover in a region of intensive agricultural activity (Gould and Jenkins 1993, Grovenburg et al. 2011a); thus, we hypothesized that fawns would select for CRP in an area with limited permanent cover. Additionally, reductions in CRP enrollments during our study provided a unique opportunity to evaluate neonate ecology during a period of changing availability of habitat in the region. Because fawns are most vulnerable to predation and death by natural causes during the first few months of life (Verme 1977, Huegel et al. 1985a, Nelson and Woolf 1987), change in availability of cover habitat could influence deer population management in grassland regions. Therefore, we hypothesized that loss of CRP grasslands would lead to larger home ranges and movements as well as changes in selection of other cover types.

STUDY AREA

During 2007–2009, we searched for neonatal white-tailed deer throughout Edmunds and Faulk counties (Fig. 1) in north-central South Dakota; the 2 counties comprised 5,558 km^2. Mean annual (30-years) precipitation was 49.5 cm and mean summer (30-years) temperature ranged from 18.2° C to 21.3° C (South Dakota Office of Climatology 2010). The area was located within the Northwestern Glaciated Plains and the Northern Glaciated Plains Level III Ecoregions and the landscape was flat to gently rolling terrain intermixed with pothole wetlands and mounds of glacial till (Bryce et al. 1998). Soils in the study area were dominated by Williams-Bowbells and Williams-Bowbells-Vida associations (Ensz 1977, Miller 1984). Land use in the 2 counties was dominated by agriculture, with cultivated land and pasture constituting 40.4% and 43.0%, respectively, of total land use; average forested (mainly woodland plantings and shelterbelts) cover was about 2.3% (Smith et al. 2002). South Dakota had 631,704 ha enrolled in the 2006 CRP with 14,975 ha in the 2-county area (2.7% total land cover; South Dakota Agriculture Statistics Service 2009). Minimum summer deer densities within the study area were estimated at 2.3–3.3 deer/km^2 (Grovenburg et al. 2009a).

Traditionally, white-tailed deer on the northern Great Plains select habitats consisting of draws, swales, and
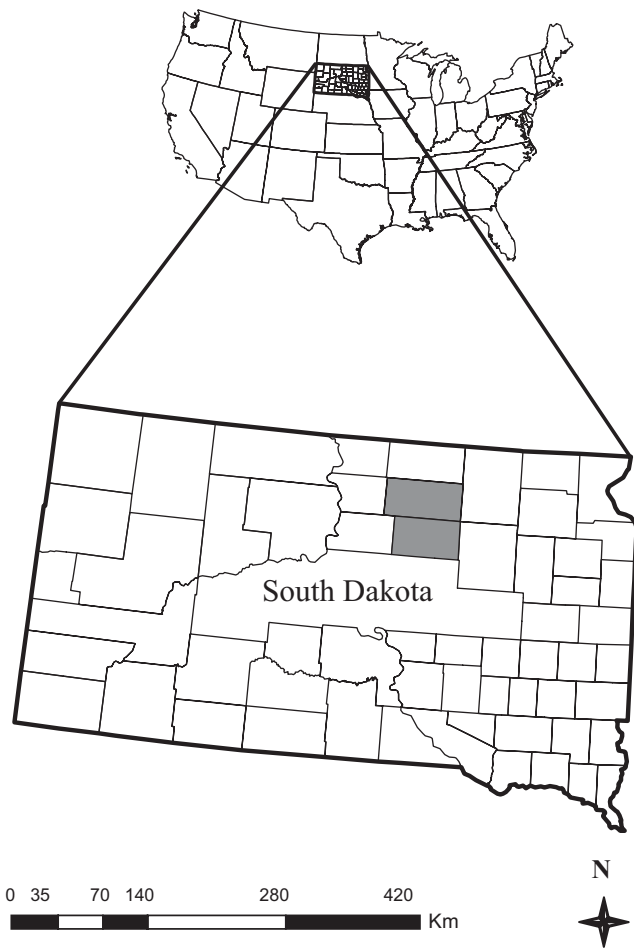
Figure 1. Two-county (Edmunds and Faulk) area for study of spatial ecology of fawn white-tailed deer (*Odocoileus virginianus*) in north-central South Dakota, USA, 2007–2009.

METHODS

We captured fawns during 15 May to 15 June 2007–2009 using nocturnal searches with vehicles and daytime ground searches using postpartum behavior of females as an indicator of parturition and presence of neonates (Downing and McGinnes 1969, White et al. 1972, Huegel et al. 1985*b*); 86.4% of fawns were captured in southern Edmunds and northern Faulk counties. Teams of 2–5 people intensively searched areas where we observed isolated females, females attempting to hide by lowering themselves to the ground, and females fleeing short distances as vehicles approached (Downing and McGinnes 1969, White et al. 1972, Huegel et al. 1985*b*). Once a neonate was visually located, we used a quick and loud approach to initiate a drop response (Nelson and Woolf 1987). We pursued neonates on foot that attempted to flee and captured them with hand-held nets (Ranger Salmon Net; Ranger Products, Inc., Detroit, MI).

We manually restrained neonates, recorded duration of chase, and determined sex. We determined age using hoof-growth measurement and umbilicus condition (Haugen and Speake 1958, Brinkman et al. 2004*b*). We weighed individuals to the nearest gram using a 4.8-mm mesh bag suspended from a digital scale (Model FS 50, Berkley, Spirit Lake, IA) and recorded habitat type in which neonates were captured. We recorded capture locations (Universal Transverse Mercator [UTM]; Zone 14 NAD 83 coordinates) using a Magellan Triton 1500 Global Positioning System (GPS; Magellan Navigation, Inc., Santa Clara, CA), fitted captured neonates with model M4210 expandable breakaway radiocollars (Advanced Telemetry Systems, Isanti, MN), and recorded handling time. To help minimize stress and reduce capture-related mortality, we minimized handling time (<4 min), processed fawns at capture sites, wore sterile rubber gloves, stored radiocollars and other equipment for 6 weeks before capture in natural vegetation commonly found in the area, kept noise to a minimum, and rubbed fawns with native vegetation before release. Animal handling methods used in this project followed guidelines approved by the American Society of Mammalogists (Sikes et al. 2011) and were approved by the Institutional Animal Care and Use Committee at South Dakota State University (approval number 04–A009).

We collected locations on each fawn from time of capture until 31 August each summer. We located fawns 2 times/day using a truck-mounted null-peak antenna system with an electronic digital compass (C100 Compass Engine, KVH Industries, Inc., Middletown, RI; Brinkman et al. 2002) and a hand-held 4-element Yagi antenna (Advanced Telemetry Systems). We visually located fawns and recorded UTM coordinates using a handheld GPS or estimated animal locations using LOCATE III (Nams 2006) with a minimum of 3 azimuths per location. We collected locations on a rotational schedule using 8-hour time intervals (i.e., 0600–1400 hours, 1400–2200 hours, and 2200–0600 hours) for each fawn and avoided obtaining locations during the same interval on successive location attempts. We excluded

lowlands that received greater moisture than surrounding areas (Petersen 1984). Although marshes and sloughs occupy a relatively small portion of the northern Great Plains (11.1% land use in 2-county area; Smith et al. 2002), they serve as cover and foraging areas for deer throughout the region (Petersen 1984). The Northern Mixed Grass Prairie extends in an arc below the boreal forests of Canada and into east-central South Dakota (Johnson and Larson 1999). Native vegetation was predominately western wheatgrass (*Elymus smithii*), big bluestem (*Andropogon gerardii*), porcupine grass (*Stipa spartea*), and little bluestem (*Schizachyrium scoparium*). Dominant tree species were green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), boxelder (*Acer negundo*), hackberry (*Celtis* spp.), and eastern cottonwood (*Populus deltoides*; Petersen 1984, Johnson and Larson 1999). Common wetland vegetation included prairie cordgrass (*Spartina pectinata*), reed canarygrass (*Phalaris arundinacea*), common reed (*Phragmites australis*), cattails (*Typha* spp.), rushes (*Juncus* spp.), and sedges (*Carex* spp.; Johnson and Larson 1999). Cultivated crops included corn (*Zea mays*), soybeans (*Glycine max*), wheat (*Triticum aestivum*), and alfalfa (*Medicago sativa*; South Dakota Agriculture Statistics Service 2009).

locations with 95% error ellipses ≥20 ha from our analyses (Brinkman et al. 2005).

We calculated parturition date from fawn age at capture (Nelson and Woolf 1985, Rohm et al. 2007). We determined birth mass from age and weight at capture for each fawn using previous estimates of mean daily mass gain for fawns (0.25 kg; Robbins and Moen 1975, Nelson and Woolf 1985) multiplied by estimated age of fawn at capture and subtracted from mass of fawn at capture (Kunkel and Mech 1994, Rohm et al. 2007). We assumed capture mass of fawns <1-day-old equaled birth mass. We used analysis of variance (ANOVA) to evaluate capture age and estimated birth mass by sex and capture year.

We used the fixed-kernel method in Home Range Tools (HRT) for ArcGIS 9.2 (ESRI, Inc., Redlands, CA; Rodgers et al. 2007) to calculate 95% and 50% (core) home ranges and temporal movement between locations (distance between successive locations). We calculated home ranges using an ad hoc smoothing parameter ($h_{ad\ hoc}$) by choosing the smallest increment of the reference bandwidth (h_{ref}) that resulted in a contiguous 95% kernel home range (i.e., $h_{ad\ hoc} = 0.9 \times h_{ref}$, $0.8 \times h_{ref}$, etc.; Klaver et al. 2008, Jacques et al. 2009). Kernel estimators are nonparametric and thus, are not based on an assumption that the data conform to specified distribution parameters (Seaman et al. 1999). We constructed fawn home ranges from capture date to 31 August for each year using a minimum of 30 locations for each home range (Seaman et al. 1999). We used ANOVA to determine differences in summer home range size and movement (distance between successive locations) of fawns among years. We used a t-test to determine differences in summer home range size and movement between male and female fawns.

We used individual fawn home ranges to assess available land cover and to determine whether habitat characteristics and declining CRP enrollments influenced fawn ecology. Because of mortality and censoring due to collar drop during the first 30 days post-capture, we were unable to calculate home ranges for 11 fawns. Therefore, we created buffered areas around capture locations based on age of fawn at time of mortality or censoring (Rohm et al. 2007). During 2007–2009, buffered areas were 48.2 ha, 61.3 ha, and 83.8 ha, respectively, corresponding to mean 30-day fawn home-range size each year. We used ArcGIS 9.2 to analyze available land cover. We ground verified individual habitats and annual land use changes (i.e., grasslands placed into production, crop rotations) using GPS and digitized a unique map for each summer. We determined habitat characteristics for each fawn by overlaying individual home range or buffered area onto habitat maps. We classified habitat types as forested cover, CRP-grassland (including ungrazed native grasslands), pasture (including grazed native grasslands), wetland, corn, soybeans, wheat, and development (including roads), and calculated percent of each type available within each home range. We used FRAGSTATS Version 3.3 to calculate landscape and class-level metrics associated with each home range or buffered area (McGarigal et al. 2002). We defined fawn study area as southern Edmunds and

northern Faulk counties where we captured 86.4% of fawns. To quantify habitat within the entire fawn study area, we used a buffered (1,000-m buffer equal to mean core home range of adult females; Grovenburg et al. 2009b) minimum convex polygon around all fawn locations and calculated percent of each habitat type available each year.

We modeled individual fawn home ranges and buffered areas for our analyses and selected the initial set of landscape and class-level metrics correlated with fawn use based on neonatal ecology and previous studies (Vreeland et al. 2004, Rohm et al. 2007, Grovenburg et al. 2011b). We grouped metrics into 6 categories: patch, edge, shape, proximity, diversity, and contagion (McGarigal et al. 2002). Because metrics within each FRAGSTATS category often are correlated (Hargis et al. 1998), we selected only 2 metrics within each category (Kie et al. 2002). To test for potentially confounding relationships, we evaluated collinearity between predictor variables using Pearson's correlation coefficient ($r > |0.50|$), which resulted in 23 uncorrelated variables that were used to determine the influence of habitat characteristics and declining CRP-grasslands on fawn ecology (Table 1). Class metrics included patch density (PD; number of patches/100 ha of the habitat category), mean area (MA; mean area of land cover patches [ha] of habitat category), and shape index (SI; total length of edge [or perimeter] associated with the corresponding habitat, divided by the minimum length of habitat edge [or perimeter] possible for a maximally aggregated habitat). Landscape metrics included number of patches (NP; number of total patches in the area), landscape patch density (LPD; total number of patches in the area/ 100 ha), landscape shape index (LSI; total length of edge in the landscape, divided by the minimum total length of edge possible), and coefficient of variation (CV; a measure of patch area distribution; McGarigal et al. 2002).

We used analysis of covariance (ANCOVA) to determine influence of habitat characteristics and declining CRP-grasslands on home-range size and movement and posited 18 a priori models (Table 2) of how fawn home range and movement might be influenced by changes in land cover. We set year as a classification variable and selected model parameters based on fawn ecology. We used Akaike's information criterion (AIC) to select models that best described the data. We compared AIC values to select the most parsimonious model and considered models differing by ≤2 ΔAIC from the selected model as potential alternatives (Burnham and Anderson 2002). We used Akaike weights (w_i) as an indication of support for each model and used multi-model inference to average parameters across competing models. We examined models ≤2 ΔAIC from the best model to determine if they contained ≥1 parameter more than the best model but had essentially the same maximized log-likelihood as the best model. In these cases, we considered models with additional parameters unsupported and non-competitive, as they were only considered potential models because they contributed an additional parameter (Burnham and Anderson 2002, Arnold 2010). Thus, we eliminated these models from consideration in our analyses.

Table 1. Final variables (including mean, SD, and range) measured within fawn white-tailed deer home ranges used to estimate the influence of habitat characteristics on fawn home range size and daily movement, and to determine summer fawn resource selection in north-central South Dakota, USA, 2007–2009.

Variable	No.	Mean (SD)	Range	Definition[a]
CRP-grassland	1	31.6 (26.8)	0.0–95.8	Total Conservation Reserve Program (CRP)-grassland cover (%)
Forested cover	2	3.4 (1.4)	0.0–5.9	Total forested cover (%)
Wheat cover	3	17.8 (16.2)	0.0–64.6	Total wheat cover (%)
Cropland cover	4	24.5 (16.9)	0.0–70.0	Total cropland cover (%)
Wetland cover	5	2.5 (2.5)	0.0–10.6	Total wetlands (%)
CRP-grassland patch density	6	1.6 (0.8)	0.0–2.6	Density (no./100 ha) of CRP-grassland patches
$\overline{X}$ CRP-grassland patch area	7	24.4 (23.6)	0.0–112.4	Average patch size (ha) for all CRP-grassland patches
CRP-grassland shape index	8	1.5 (0.5)	0.0–2.6	Average departure of CRP-grassland patches from max. compaction
Forested patch density	9	0.8 (0.7)	0.0–2.6	Density (no./100 ha) of forested patches
$\overline{X}$ forested patch area	10	0.3 (0.3)	0.0–1.3	Average patch size (ha) for all forest patches
Forest shape index	11	0.7 (0.6)	0.0–1.4	Average departure of forest patches from max. compaction
Wetland patch density	12	1.7 (1.1)	0.0–5.1	Density (no./100 ha) of wetland patches
Mean wetland patch area	13	1.4 (0.8)	0.0–3.6	Average patch size (ha) for all wetland patches
Wetland shape index	14	1.4 (0.6)	0.0–2.3	Average departure of wetland patches from max. compaction
Cultivated patch density	15	2.2 (1.3)	0.0–6.4	Density (no./100 ha) of cultivated patches
Mean cultivated patch area	16	14.2 (14.2)	0.0–64.0	Average patch size (ha) for all cultivated patches
Cultivated shape index	17	1.5 (0.6)	0.0–3.1	Average departure of cultivated patches from max. compaction
Wheat patch density	18	1.2 (1.2)	0.0–6.4	Density (no./100 ha) of wheat patches
Mean wheat patch area	19	17.4 (21.0)	0.0–63.9	Average patch size (ha) of wheat patches
Wheat shape index	20	1.0 (0.7)	0.0–1.7	Average departure of wheat patches from max. compaction
Patch density	21	10.3 (3.5)	2.9–18.5	Total number of patches in the area/100 ha
Landscape shape index	22	5.2 (1.3)	2.5–7.4	Standardized measure of the amount of edge for all habitat patches
Mean patch area	23	7.1 (5.6)	2.3–39.1	Average patch size (ha) for all habitat patches
Coefficient of variation	24	240.6 (64.7)	128.9–397.3	Mean coefficient of variation of patch size for all habitat patches

[a] Variables are further defined in McGarigal et al. (2002).

We collected an equal number of diurnal and nocturnal locations to minimize temporal bias in home-range analyses. To determine whether fawn use of CRP varied during summer months and whether use of corn during late summer was similar between fawns and adult deer (Kernohan 1994), we used K-Means analysis to cluster individual fawn locations by date using Euclidean distance (coordinates of fawn locations; Boulanger et al. 2006) and calculated 95% home

Table 2. A priori analysis of covariance models constructed to determine the influence of habitat variables on fawn white-tailed deer home-range size and daily movement in north-central South Dakota, USA, 2007–2009. We set year as our classification covariate.

Model	Variables[a]
CRP	1
CRP metrics	6–8
Forested metrics	9–11
Wetland metrics	12–14
Cropland metrics	15–17
Wheat metrics	18–20
Wheat	3
CRP + wheat	1, 3
Landscape	21–24
Cropland	4
Wetland	5
Forested	2
Landscape + CRP metrics	6–8, 21–24
Landscape + FC metrics	9–11, 21–24
Landscape + wetland metrics	12–14, 21–24
Landscape + crop metrics	15–17, 21–24
Landscape + wheat metrics	18–20, 21–24
CRP + forested	1, 2

CRP, Conservation Reserve Program.
[a] Variables included in model numbered in Table 1.

ranges for each cluster. Because use of corn by adult deer occurred with increasing height of corn (Kernohan 1994), we used a Robel pole (Robel et al. 1970) to estimate vertical height of corn 2–3 times/week at 20 random sites (2–3 random points per field of corn). At each random point, we measured vertical height of corn at the center of the random site and at 4 locations 2 m from the random site along 2 perpendicular transects originating at the random site.

We calculated resource selection for clusters using a design III analysis (Manly et al. 2002) to determine whether selection was positive, negative, or neutral for habitat categories. We used Program R version 2.10.1 (http://www.r-project.org/index.html, accessed 22 Sep 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 individual level (design III; individual home range); we calculated selection ratios as use/availability (Manly et al. 2002). Design III analysis measured use and availability of resource units separately for each fawn (Manly et al. 2002). For design III analysis, selection of a habitat was indicated if the selection ratio ($\hat{w}$) differed significantly from 1 (no overlap in confidence intervals; Manly et al. 2002). We set $\alpha = 0.10$ (Morrison et al. 1998, Klaver et al. 2008).

We used logistic regression to test for a functional response (Mysterud and Ims 1998) by fawns in CRP use (i.e., a change in relative use [$\rho(u)$] with changing availability [$\rho(a)$]). With an appropriately fitted model ($P > 0.05$), an estimated slope (β) parameter $\neq 1$ indicated functional response, whereas a

slope equal to 0 indicated 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 (i.e., $\rho(u)|\rho(a) > \rho(a)$; Mysterud and Ims 1998).

RESULTS

We captured and radiocollared 81 fawns (51 F, 30 M) during 15 May to 15 June 2007 ($n = 22$, 14 F:8 M), 2008 ($n = 27$, 17 F:10 M), and 2009 ($n = 32$, 20 F:12 M). Mean search-hours and man-hours per captured fawn was 5.1 hours and 10.1 hours, respectively. Median dates of parturition were 26 May 2007, 26 May 2008, and 29 May 2009. Eighty-six percent of fawns were ≤1 week old at capture, which included 41 newborns (<2 days old). Estimated ages of fawns at capture ranged from 0.5 days to 12.5 days, and averaged 3.2 days (SE = 0.3, $n = 81$). Estimated age at capture did not vary by sex ($F_{1,79} = 0.53$, $P = 0.47$) but varied by year ($F_{2,78} = 27.82$, $P < 0.001$); fawns were older at capture during 2007 ($\overline{X} = 6.0$ days, SE = 0.6, $n = 27$) than 2008 ($\overline{X} = 1.87$ days, SE = 0.3, $n = 22$) and 2009 ($\overline{X} = 1.84$ days, SE = 0.3, $n = 32$). Estimated birth mass ($\overline{X} = 2.65$ kg, SE = 0.04, $n = 81$) differed by sex ($F_{1,79} = 7.90$, $P = 0.01$) but not year ($F_{2,78} = 0.42$, $P = 0.66$). Males ($\overline{X} = 2.81$ kg, SE = 0.05, $n = 30$) weighed more than females ($\overline{X} = 2.56$ kg, SE = 0.04, $n = 51$). Available CRP-grassland in the study area decreased from 5.7% to 3.4% of available land cover from 2007 to 2009; a decrease of approximately 21% of available cover habitat (Table 3).

We located fawns 6,505 times (74.8% visual locations); mean 95% error ellipse was 4.8 ha. We documented 70 summer home ranges during 3 periods: summer 2007 ($n = 21$), summer 2008 ($n = 23$), and summer 2009 ($n = 26$). We calculated individual home ranges for each summer using a minimum of 32 and a mean of 88.9 (SD = 18.5, range 32–108, $n = 70$) locations. Because of mortality or collar loss, we censored 11 fawns with

<30 locations from home range analyses. Summer home ranges (95%) during 2007–2009 averaged 92.2 ha (SE = 14.4, $n = 21$), 136.9 ha (SE = 18.6, $n = 23$), and 193.7 ha (SE = 8.9, $n = 26$), respectively, and differed ($F_{2,67} = 12.99$, $P < 0.001$) among years. Core home ranges during 2007–2009 averaged 20.5 ha (SE = 3.0, $n = 21$), 39.8 ha (SE = 2.8, $n = 23$), and 56.8 ha (SE = 2.1, $n = 26$), respectively, and differed ($F_{2,67} = 48.24$, $P < 0.001$) among years. Similarly, mean movement between successive daily locations increased ($F_{2,67} = 14.07$, $P < 0.001$) each year and was 291.7 m (SE = 21.4, $n = 21$), 396.7 m (SE = 34.6, $n = 23$), and 497.2 m (SE = 28.0, $n = 26$), respectively. Fawns were capable of extensive movements; 53.6% of fawns made movements >1 km (range = 1–5.8 km) prior to 30 days of age. Moreover, percentage of fawns <30 days of age that made movements >1 km increased each year (33.3%, 2007; 52.7%, 2008; 72.0%, 2009). Mean 95% summer home range ($t_{68} = 0.74$, $P = 0.46$), core home range ($t_{68} = 1.29$, $P = 0.20$), and movement between locations ($t_{68} = 0.18$, $P = 0.86$) were similar for male and female fawns.

A priori ANCOVA models estimating influence of habitat variables on home-range size indicated that changes in CRP availability influenced fawn home-range size during 2007–2009 ($w_i = 0.88$, $F_{5,64} = 23.79$, $P < 0.001$, $R^2 = 0.65$; Table 4). This model was >2 ΔAIC units from remaining models and weight of evidence supporting this model was 14.7 times greater than the second and third best models and 880.0 times ≥ remaining models. Parameter estimates (Table 5) indicated that home-range size was negatively associated with percentage of CRP in the home range; fawn home-range size decreased by 2.4 ha, 1.1 ha, and 2.5 ha for each 1% increase in CRP during 2007, 2008, and 2009, respectively.

We considered models [CRP|year + wheat|year] and [CRP|year] as supported by the data for estimating influence of habitat variables on daily movement (Table 4). These models were ≤1 ΔAIC units from each other and we interpreted both to account for model uncertainty; remaining

Table 3. White-tailed deer fawn study area and home range habitat composition (percent) in north-central South Dakota, 2007–2009.

Habitat	2007		2008		2009	
	Area[a]	HR[b]	Area	HR	Area	HR
Forested	1.9	2.8	1.9	3.9	1.9	3.5
CRP[c]	5.7	46.7	4.3	29.4	3.4	21.4
Wetland	1.0	3.1	1.2	2.9	1.5	1.7
Wheat	19.8	6.3	22.4	22.5	25.6	23.0
Cropland[d]	37.8	36.2	36.0	19.8	33.1	19.2
Pasture	29.7	5.7	30.1	18.4	30.4	31.0
Development	4.1	0.4	4.1	1.4	4.1	0.5

[a] Fawn study area.
[b] 95% kernel home range.
[c] Conservation Reserve Program grasslands.
[d] Corn and soybeans.

Table 4. Top-ranked analysis of covariance models used to estimate home range size and daily movement of fawn white-tailed deer in north-central South Dakota, USA, 2007–2009.

Model[a]	K[b]	AIC[c]	ΔAIC[d]	w_i[e]
Home range				
CRP|year	8	284.99	0.00	0.88
CRP|year + wheat|year	12	290.25	5.26	0.06
Wheat|year	8	290.39	5.41	0.06
CRP|year + forested|year	12	297.76	12.77	0.00
Movement				
CRP|year + wheat|year	12	301.10	0.00	0.51
CRP|year	8	301.25	0.15	0.47
CRP|year + forested|year	12	308.05	6.95	0.02
CRPmetrics|year	16	327.28	26.18	0.00

[a] Composition and description of models are listed in Table 2. CRP = Conservation Reserve Program grasslands.
[b] Number of parameters.
[c] Akaike's information criterion (Burnham and Anderson 2002).
[d] Difference in AIC relative to the minimum AIC.
[e] Akaike weight (Burnham and Anderson 2002).

Table 5. Parameter estimates (β), 95% confidence intervals, and significance tests from the top-ranked analysis of covariance model to determine the influence of habitat variables on home range size of fawn white-tailed deer in north-central South Dakota, USA, 2007–2009.

Parameter[a]	β	95% CI	t-value	P-value
Intercept	198.2	162.72–249.61	16.10	<0.001
CRP	−2.5	−3.28 to −1.72	12.20	<0.001
Year—2007	−37.1	−63.56 to −10.84	−3.14	<0.01
Year—2008	31.9	3.28–60.52	−2.13	0.04
Year—2009[b]	0.0			
CRP × year—2007	0.1	0.03–0.07	11.76	<0.001
CRP × year—2008	1.4	−0.85 to 3.75	−0.19	0.85
CRP × year—2009[b]	0.0			

[a] CRP = percent Conservation Reserve Program grasslands in home ranges of individual fawns.
[b] 2009 was baseline year in analysis of covariance model.

models were >6.9 ΔAIC units from the top model. Model [CRP|year + wheat|year] ($w_i = 0.51$, $F_{8,61} = 301.10$, $P < 0.001$, $R^2 = 0.86$) had the lowest AIC value and weight of evidence supporting this model was 1.08 times greater than the second best model and 25.5 times $\geq$ remaining models (Table 4). Parameter estimates (Table 6) indicated that variation in fawn movement was best explained by percentage of CRP and wheat in fawn home range areas. Fawn movements increased by 3.4 m, 5.2 m, and 4.6 m for every 1% decrease in CRP and by 1.0 m, 2.1 m, and 0.3 m for every 1% increase in wheat during 2007, 2008, and 2009, respectively. Model [CRP|year] ($w_i = 0.47$, $F_{5,64} = 74.98$, $P < 0.001$, $R^2 = 0.85$) indicated that variation in movement was best explained by percentages of CRP in fawn home range areas (Table 4); parameter estimates (Table 6) indicated that longer movements corresponded with smaller percentages of CRP in home ranges. Similar to model [CRP|year + wheat|year], fawn movements increased by 4.7 m, 5.3 m, and 4.7 m for every 1% decrease in CRP during 2007, 2008, and 2009, respectively.

Cluster analysis indicated that individual fawn locations were grouped into 2 clusters; Euclidean distance between locations shifted in x and y coordinate space during summer. Mean date of annual cluster shift during 2007–2009 was 12 July, 23 July,

and 17 July, respectively. Mean age at movement between clusters during 2007–2009 was 48.8 (SE = 3.2, $n = 17$), 58.6 (SE = 1.8, $n = 23$), and 53.1 days (SE = 1.6, $n = 25$), respectively, and differed ($F_{2,62} = 5.14$, $P = 0.009$) across summers. Mean height of corn at the time of movement during 2007–2009 was 83.2 cm (SE = 1.1, $n = 100$), 85.1 cm (SE = 1.7, $n = 100$), and 86.7 cm (SE = 1.9, $n = 100$), respectively, and was similar ($F_{2,297} = 1.19$, $P = 0.307$) across summers. For resource selection, we calculated ad hoc ($h_{ad\ hoc}$) home ranges for each cluster (early and late) using a minimum of 30 and a mean of 39.4 (SD = 6.3, range = 30–57, $n = 120$) locations.

During early summer (cluster 1), fawns did not randomly select habitat in proportion to availability during 2007 ($\chi^2_{60} = 91.12$, $P = 0.006$), 2008 ($\chi^2_{99} > 999.00$, $P < 0.001$), and 2009 ($\chi^2_{103} = 173.30$, $P < 0.001$; Table 7). Fawns selected for CRP habitat greater than expected by chance during all 3 summers (early period, cluster 1) and for wheat during 2009; deer avoided pasture during all 3 summers and wheat during 2007. During late summer (cluster 2), fawns did not randomly select habitat in proportion to availability during 2007 ($\chi^2_{61} > 999.00$, $P < 0.001$), 2008 ($\chi^2_{67} > 999.00$, $P < 0.001$), and 2009 ($\chi^2_{69} = 84.91$, $P = 0.09$; Table 8). Fawns selected for corn during all 3 summers and CRP during 2008; deer avoided wheat during all 3 summers.

Analysis of functional assessment during early summer for CRP ($\chi^2_8 = 12.69$, $P = 0.12$) indicated good model fit. Confidence intervals for β (Table 9) indicated an increase in CRP use as CRP availability increased. The regression curve and its lower confidence bound indicated that selection for CRP occurred only for proportion available [$\rho(a)$] < 0.63 (Fig. 2A). The regression model based on all individuals during late summer was a poor fit to the data ($\chi^2_8 = 16.71$, $P = 0.03$; Table 9). Inspection of the residuals from the model suggested that lack of fit was due to deviating CRP use by a single fawn in year 2007 with an intermediate proportion of CRP habitat in its home range (Fig. 2B). To obtain an appropriate model fit, we removed this outlier from the analysis (Mysterud and Ims 1998); the resulting regression model ($\chi^2_8 = 12.65$,

Table 6. Parameter estimates (β) and confidence intervals from top-ranked analysis of covariance models ([CRP + wheat] and [CRP]) to determine the influence of habitat variables on movement of fawn white-tailed deer in north-central South Dakota, USA, 2007–2009.

Parameter[a]	CRP + wheat				Parameter[a]	CRP			
	β	95% CI	t-value	P-value		β	95% CI	t-value	P-value
Intercept	588.9	493.20–684.53	12.31	<0.001	Intercept	598.6	566.36–630.84	37.09	<0.001
CRP	−464.8	−597.49 to −332.13	−7.01	<0.001	CRP	−474.24	−574.29 to −374.19	−9.47	<0.001
Year—2007	−145.8	−21.39 to −270.2	−2.34	0.02	Year—2007	−133.42	−200.89 to −65.96	−3.95	<0.01
Year—2008	−121.1	27.96 to −270.20	−1.62	0.11	Year—2008	−45.17	−95.85 to 5.49	−1.78	0.08
Year—2009[b]	0.0				Year—2009[b]	0.0			
CRP × year—2007	127.1	17.54–236.66	1.33	0.19	CRP × Year—2007	103.22	−47.72 to 254.15	1.37	0.18
CRP × year—2008	−59.8	−172.14 to 291.77	0.52	0.61	CRP × Year—2008	−59.57	−201.45 to 82.29	−0.84	0.40
CRP × year—2009[b]	0.0				CRP × Year—2009[b]	0.0			
Wheat	33.5	3.0–63.99	2.11	0.04					
Wheat × year—2007	69.2	−327.37 to 465.78	0.35	0.73					
Wheat × year—2008	178.9	−230.13 to 587.96	0.87	0.39					
Wheat × year—2009[b]	0.0								

[a] CRP = percent Conservation Reserve Program grasslands in home ranges of individual fawns; wheat = percent wheat in home ranges of individual fawns.
[b] 2009 was baseline year in analysis of covariance models.

Table 7. Estimated selection ratios and confidence intervals for early summer (cluster 1) habitat selection of fawn white-tailed deer ($n = 65$) in north-central South Dakota, 2007–2009, using design III (Manly et al. 2002).

| | 15 May to 12 Jul 2007 | | | 15 May to 23 Jul 2008 | | | 15 May to 17 Jul 2009 | | |
| | | 90% CI | | | 90% CI | | | 90% CI | |
Habitat[a]	Ratio ($\hat{w}$)	Lower	Upper	Ratio ($\hat{w}$)	Lower	Upper	Ratio ($\hat{w}$)	Lower	Upper
Soybeans	0.70[−]	0.480	0.919	0.76	0.439	1.093	0.63[−]	0.387	0.882
Corn	0.63[−]	0.460	0.861	0.79	0.561	1.021	0.31[−]	0.231	0.395
CRP	1.27[+]	1.151	1.364	1.38[+]	1.058	1.682	1.37[+]	1.177	1.561
Forested	1.07	0.617	1.513	1.67	0.944	2.406	1.32	0.906	1.724
Pasture	0.57[−]	0.442	0.701	0.53[−]	0.165	0.901	0.61[−]	0.478	0.731
Wheat	0.44[−]	0.18	0.708	0.90	0.694	1.103	1.31[+]	1.105	1.523
Wetland	0.95	0.539	1.369	1.10	0.580	1.630	0.86	0.582	1.148
Development	0.18[−]	0.000[b]	0.400	0.53	0.000[b]	1.072	0.71	0.377	1.040

[+] Indicates that the selection coefficient $\hat{w}$ was significantly different from 1 and the habitat was used more than expected from the availability of this habitat.
[−] Indicates that the selection coefficient $\hat{w}$ was significantly different from 1 and the habitat was used less than expected from the availability of this habitat.
[a] Pasture included alfalfa and development included roads, CRP = Conservation Reserve Program grasslands.
[b] Negative lower limit changed to 0.000.

$P = 0.13$) indicated good model fit. Slope and intercept remained constant as to selection for both late-summer models (Table 9); therefore, we could make reliable inferences about CRP selection during late summer. Confidence interval estimates for β indicated use of CRP increased as availability increased during late summer.

DISCUSSION

Our results demonstrated that abundance of CRP-grasslands influenced fawn home range size, daily movements, and resource selection. Loss of CRP grassland observed during our study was representative of regional changes in enrollment. Although absolute loss in the study area was only 2.3% of total land cover, this represented a loss of approximately 21% of total cover habitat. From spring 2007 to late summer 2009 in South Dakota, 23% of CRP-grasslands were converted into agricultural production (United States Department of Agriculture 2011). Furthermore, an additional 20.5% were due to expire 30 September 2009 (of which 14.7% expired; United States Department of Agriculture 2011), with 330,044 ha (68% of remaining CRP-grasslands) expiring by fall 2013 (United States Department of

Agriculture 2011). Similar CRP losses have been observed and are projected for surrounding states (Iowa, Minnesota, Montana, Nebraska, and North Dakota). Losses of CRP-grassland ranged from 8% to 15% between spring 2007 and late summer 2009 in surrounding states, with an additional 9–20% expiring during fall 2009. Between 2009 and 2013, an additional 2.7 million ha (48–69% of remaining CRP-grasslands) are due to expire in surrounding states (United States Department of Agriculture 2011) and no alternative farm bill programs are being considered in current legislative sessions.

Fawn home ranges and daily movements in grassland habitats of our study area in the northern Great Plains increased in size with loss of enrolled CRP land from 2007 to 2009. On the northern Great Plains, previous studies indicated that adult deer used CRP for bedding and forage (Gould and Jenkins 1993, Grovenburg et al. 2010a, b), whereas neonates selected bed sites in CRP-grasslands; vertical structure provided thermal insulation as well as cover and concealment from predators (Grovenburg et al. 2010a). We hypothesize that with limited forested cover in the region, fawns and dams have adopted use of

Table 8. Estimated selection ratios and confidence intervals (cluster 2) habitat selection of white-tailed deer fawns ($n = 65$) in north-central South Dakota, 2007–2009, using design III (Manly et al. 2002).

| | 13 Jul to 31 Aug 2007 | | | 24 Jul to 31 Aug 2008 | | | 18 Jul to 31 Aug 2009 | | |
| | | 90% CI | | | 90% CI | | | 90% CI | |
Habitat[a]	Ratio ($\hat{w}$)	Lower	Upper	Ratio ($\hat{w}$)	Lower	Upper	Ratio ($\hat{w}$)	Lower	Upper
Soybeans	0.91	0.441	1.383	0.57[−]	0.388	0.746	0.30[−]	0.127	0.478
Corn	1.33[+]	1.120	1.549	1.33[+]	1.088	1.515	1.25[+]	1.095	1.407
CRP	0.91	0.795	1.019	1.17[+]	1.006	1.308	1.06	0.926	1.189
Forested	1.06	0.689	1.435	1.09	0.575	1.606	1.11	0.683	1.529
Pasture	0.29[−]	0.000[b]	0.687	0.34[−]	0.011	0.673	0.72	0.355	1.093
Wheat	0.33[−]	0.046	0.612	0.65[−]	0.346	0.963	0.23[−]	0.091	0.374
Wetland	1.05	0.661	1.495	1.25	0.396	2.112	0.50[−]	0.061	0.942
Development	0.14[−]	0.000[b]	0.329	0.44[−]	0.029	0.853	0.75	0.132	1.359

[+] Indicates that the selection coefficient $\hat{w}$ was significantly different from 1 and the habitat was used more than expected from the availability of this habitat.
[−] Indicates that the selection coefficient $\hat{w}$ was significantly different from 1 and the habitat was used less than expected from the availability of this habitat.
[a] Pasture included alfalfa and development included roads. CRP = Conservation Reserve Program grasslands.
[b] Negative lower limit changed to 0.000.

Table 9. Parameter estimates (point estimates and 95% confidence limits) for the logistic regression equation logit (proportion used) = $\alpha + \beta$ logit (proportion available) for Conservation Reserve Program (CRP) grassland data from fawn white-tailed deer in north-central South Dakota, USA, 2007–2009.

Model[a]	n[b]	Intercept		Slope	
		α	95% CL	β	95% CL
CRP—cluster 1	65	0.44	0.35–0.53	0.41	0.33–0.49
CRP—cluster 2	55	−0.06	−0.21 to 0.08	0.89	0.76–1.03
CRP—cluster 2[c]	54	−0.04	−0.18 to 0.11	0.90	0.77–1.04

[a] Cluster 1, early summer, included 15 May to 12 Jul 2007, 15 May to 23 Jul 2008, and 15 May to 17 Jul 2009; cluster 2, late summer, included 13 Jul to 31 Aug 2007, 24 Jul to 31 Aug 2008, and 18 Jul to 31 Aug 2009.
[b] Number of animals.
[c] One misfitting observation removed to obtain an appropriate fit ($P > 0.05$; Mysterud and Ims 1998).

CRP-grasslands. As enrolled CRP-grassland contracts expire, deer inhabiting grassland prairies in the region lose cover habitat. Consequently, deer are obligated to travel farther to find suitable cover habitat. Additional CRP losses can be expected in following years as contracts totaling
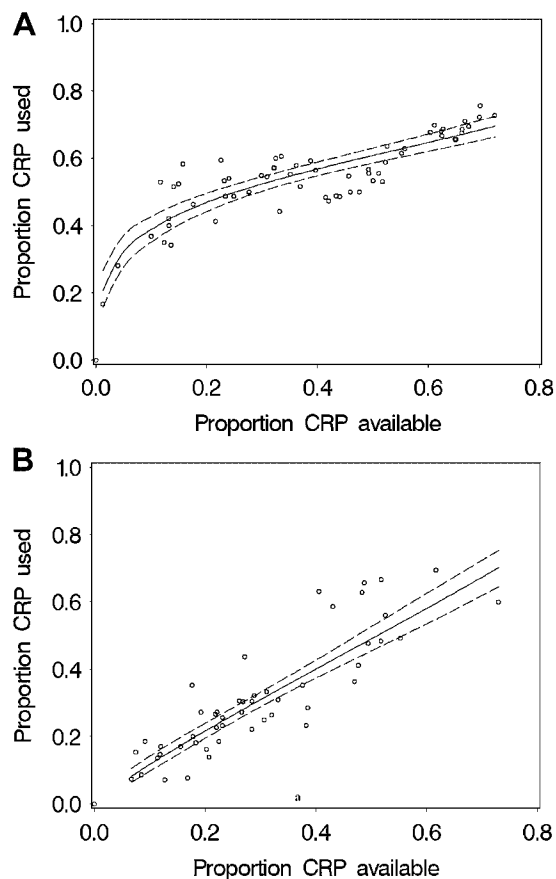

Figure 2. Logistic regression analyses of proportional use of Conservation Reserve Program (CRP) grasslands against proportion of CRP grasslands available within individual fawn white-tailed deer (*Odocoileus virginianus*) summer home ranges with 95% confidence envelopes in north-central South Dakota, USA, 2007–2009. (A) Cluster 1; early summer (15 May to 12 Jul 2007, 15 May to 23 Jul 2008, and 15 May to 17 Jul 2009), (B) cluster 2; late summer (13 Jul to 31 Aug, 24 Jul to 31 Aug, and 18 Jul to 31 Aug). We removed 1 outlier observation (a) to obtain appropriate model fit ($P > 0.05$; Mysterud and Ims 1998).

416,921 ha (86.2% of remaining enrolled land) of CRP are due to expire in South Dakota (United States Department of Agriculture 2011). Continued losses of CRP in the northern Great Plains may contribute to further fragmentation of habitats, increase in home range size and movements of deer, and reduced availability of cover habitat.

We documented larger movements and fawn home ranges than previously reported for the species; limited cover in our study area seemed to influence the size of fawn movements and home ranges. In southwestern lower Michigan, mean (27-week) home-range size for fawns was 75.4 ha and only 3 had home ranges >100 ha; however, fawn home ranges contained approximately 50% forested cover (Pusateri-Burroughs et al. 2006). Vreeland et al. (2004) reported home ranges (9-week) of 40.1–69.7 ha in central Pennsylvania with >38% forested cover. Similarly, in areas of southern Michigan that contained >25% forested cover, mean (2-month) fawn home range size was 40.9 ha (Hiller et al. 2008).

We hypothesized that fawns expanded their home ranges to include CRP and other suitable cover types. Interestingly, large fawn movement and home ranges reported during our study were similar to those previously documented for mule deer (*O. hemionus*) fawns. In Washington, mean fawn movement and home-range size was 438 m and 256.9 ha, respectively, and reflected variable home range sizes of dams (Steigers and Flinders 1980). Riley and Dood (1984) also reported variable movement and home ranges with average fawn movement and home range of 780 m and 185 ha, respectively, in the Missouri River Breaks of north-central Montana. Differences in fawn movement and home-range size between areas reflected how each population exploited available cover (Riley and Dood 1984). Large movements and home ranges described in our study suggested that larger ranges were necessary to obtain suitable cover (Garner and Morrison 1977, Steigers and Flinders 1980, Pusateri-Burroughs et al. 2006).

Habitat composition of fawn home ranges was not proportional to composition of land cover across the fawn study area. Fawn home ranges included greater proportions of cover habitats (CRP, forested cover, and wetlands) than available in the study area. Our results were similar to those in southern Michigan where home ranges were composed of a greater proportion of cover types (conifer, lowland deciduous forest) than available across the study area (Hiller et al. 2008). Conversely, Pusateri-Burroughs et al. (2006) documented use of cover proportional to composition of their study area; however, available cover during their study was approximately 9 times greater than that available in the northern Great Plains. Although availability of permanent cover was limited throughout the northern Great Plains, CRP-grasslands apparently provided fawns with increased cover during their first few months of life, perhaps minimizing risks of being encountered and subsequently killed and consumed by predators.

Percent wheat and pasture increased from 2007 to 2009, coinciding with the loss of CRP habitat during our study. As CRP-enrolled grasslands were converted to agricultural

production, percent of pasture and wheat within fawn home ranges increased by factors of 5.4 and 3.5, respectively. Grovenburg et al. (2010a) observed a shift of neonatal bed sites from CRP to wheat as available CRP decreased. Vertical height of understory vegetation was approximately 20% greater in CRP-grassland than in wheat. Because neonates rely on vertical structure for thermal insulation and concealment from predators (Huegel et al. 1986), a shift of home range area from CRP to wheat may lead to greater neonatal mortality in grassland habitats throughout the northern Great Plains. Increased pasture in home ranges from 2007 to 2009 might be explained by conversion of CRP-grasslands to row-crops and pasture. Although deer typically avoid cattle and pasture grazed by cattle (Kie et al. 1991, Fulbright and Ortega-S 2006), increasing loss of CRP cover may lead to increased occurrences of fawns traversing pasture to access suitable forage or cover. Consequently, movements across expanses of relatively open pasture likely expose fawns to a greater risk of predation.

Our hypothesis that fawns would select for CRP-grasslands during summer was supported by our results. Fawns shifted their habitat selection temporally within each summer as well as between years and showed strong selection for CRP-grasslands during early summer. Selection for CRP can be explained, in part, for fawns <30 days of age by thermal and concealment arguments (Huegel et al. 1986, Grovenburg et al. 2010a). However, selection for CRP by fawns >30 days of age suggests a different use of this habitat. Thermal insulation and concealment from predators influences fawns less as they age, whereas preference for habitat used to obtain forage increases (Van Moorter et al. 2009). Fawns begin consuming vegetation when just a few weeks old (Verme and Ullrey 1984) and become functional ruminants at approximately 2 months of age (Short 1964). Gould and Jenkins (1993) observed increased use of CRP fields by adult female deer during early summer, corresponding to a period of vegetative growth at a time when concealment cover was essential to fawn survival. Potential forage species used in CRP-grassland plantings in this region include alfalfa and sweet clover (Melilotus spp.), which grow rapidly in spring and early summer (Higgins 2000). We speculate that CRP-grasslands also serve as high-quality forage for fawns during transition from nursing to grazing.

During early summer, selection for wheat varied temporally throughout our study and corresponded with loss of CRP-grasslands, supporting our hypothesis that fawns would shift selection with declining CRP. Increased use of wheat by fawns occurred in areas where CRP grasslands were converted to crop production. Based on our analyses, fawns substituted wheat for CRP-grasslands for cover in early summer. Fawns consistently selected against pasture during early summer in all 3 years of our study. Composition of vertical structure differed significantly between pasture and CRP; vertical height of understory vegetation in CRP-grassland was at least 2 times greater than that of pasture (Grovenburg et al. 2010a), explaining early-summer avoidance. Additionally, habitat selection choices by deer, particularly for foraging habitat, may be influenced by cattle

(Cooper et al. 2008). Consistent with expectations of competition and habitat-selection theory, female mule deer shifted use from habitats preferred by cattle, and consequently increased their use of habitats avoided by cattle (Loft et al. 1991). Additionally, deer typically avoid cattle and pasture grazed by cattle (Kie et al. 1991, Fulbright and Ortega-S 2006). Although percent pasture in fawn home ranges increased temporally as a function of land use change, pasture was minimally used by fawns.

Selection for corn by fawns during late summer was similar to previous findings regarding adult use of corn in midwestern North America. Nixon et al. (1991) observed deer feeding on maturing corn throughout late summer in Illinois. Additionally, Kramlich (1985) reported that corn was the most heavily used crop in eastern South Dakota, with adult use beginning as soon as plants were tall enough (June) to provide cover. In Nebraska, female deer shifted home range centers closer to cornfields when corn was in the tassling-silking stage of development (VerCauteren and Hygnstrom 1998). In eastern South Dakota, Kernohan (1994) observed that deer use of corn was correlated with corn growth; cover characteristics of corn (i.e., height and density) increased with percent corn use by deer. The rapid growth phase of corn represented highly digestible forage rich in carbohydrates (Stoddart et al. 1975); cover characteristics of corn plants (i.e., height ≥88 cm) also were sufficient to conceal adult deer, maximizing use of cover and forage (Kernohan 1994). In north-central South Dakota, fawn movement into corn coincided with increased height of corn. Movement into corn each summer was not a function of age of fawn, but occurred when corn reached an average height of approximately 85 cm. We suspect that as corn reached a height sufficient to conceal active adult female deer, fawns followed their dams into corn for forage and cover.

During late summer, fawns used CRP-grasslands at least in proportion to availability. Gould and Jenkins (1993) observed high use of CRP fields by adult females during summer and into fall; CRP was used for active and bedded periods. However, annual differences in land-use practices (i.e., CRP emergency haying) due to drought may contribute to a reduction in CRP use during late summer (Gould and Jenkins 1993, Grovenburg et al. 2011a). After haying, collared fawns avoided CRP-grasslands in favor of other cover types (i.e., corn). We theorized that, where available, unmowed CRP-grasslands continued to provide fawns with suitable habitat for cover and forage.

Habitat quality, defined according to resource availability, cover, or predation pressure, has been identified as a significant source of variation in population dynamics of large herbivores (Coulson et al. 1999; Pettorelli et al. 2001, 2005; Klaver et al. 2008). Availability of forage at the home-range level increases survival of fawns (Van Moorter et al. 2009). Habitat quality at the home-range scale increased body mass and litter size of roe deer (Capreolus capreolus; Nilsen et al. 2004, Pettorelli et al. 2005) and spatial variation in resource availability interacted with temporal availability to improve fawn survival (Pettorelli et al. 2005). During our study, temporal

availability of CRP-grasslands in the northern Great Plains influenced fawn ecology. As CRP-grasslands were returned to agricultural crop production from 2007 to 2009, selection for wheat as a substitute for early-summer cover habitat increased. Conversion of CRP grasslands to wheat could have resulted in deer use of wheat for fawning because of successful fawning in previous years in that area. We might expect that deer would change from wheat to other habitats in the future because of low survival characteristics associated with wheat (Grovenburg et al. 2010a, in press).

MANAGEMENT IMPLICATIONS

Management of habitat throughout the grasslands of the northern Great Plains that maximizes cover would provide neonates with adequate protection from predators. We suggest that management emphasis be placed on maintaining multiple patches of grasslands and wetlands in areas used by deer for parturition and limit efforts on conserving isolated cover patches. However, continued CRP losses in the northern Great Plains will likely lead to changes in home-range use, movements, and resource selection, with a potential consequence of greater neonate mortality. We suggest further research be conducted to document potential relationships between habitats and survival of neonates occupying the northern Great Plains.

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