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ORIGINAL PAPER

Habitat selection of white-tailed deer fawns and their dams in the Northern Great Plains

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Abstract
Habitat availability can affect important life-history traits such as survival; however, little information exists on how microhabitat characteristics found at parturition sites selected by dams and bed sites selected by their offspring differ from the surrounding area and from each other. Therefore, we assessed how vegetation affected maternal parturition and offspring bed site selection for white-tailed deer (*Odocoileus virginianus*) in the Northern Great Plains. Dams selected for sites with decreased vegetation height, potentially improving their visibility, which may increase their ability to escape approaching predators. Conversely, there was no variation between vegetative characteristics at neonate bed sites and their associated random sites, indicating grasslands provide adequate concealment for neonates. Dams possess the ability to flee from approaching predators, thus increasing the importance of visibility while giving birth. Conversely, neonates depend on fear bradycardia as their main antipredator defense, so concealment is more important. Our results suggest that vegetation structure is an important characteristic to white-tailed deer as habitat needs vary between adults and neonates.

Keywords Bed site selection · Northern Great Plains · *Odocoileus virginianus* · Parturition site selection · Vegetative structure

Introduction

Habitat availability influences important life-history characteristics such as survival. For example, elk (*Cervus canadensis*) experienced increased mortality from wolves (*Canis lupus*) when using pine forests compared with

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grasslands (Hebblewhite et al. 2005) whereas resident elk decreased wolf predation risk by consuming forage located near human activity (Hebblewhite and Merrill 2009). Ciuti et al. (2014) reported mule deer (*Odocoileus hemionus*) neonate survival decreased as habitat fragmentation increased in the presence of high coyote (*Canis latrans*) populations. In contrast, elk, moose (*Alces americanus*), and white-tailed deer (*Odocoileus virginianus*) avoided direct predation risk by not selecting resources in areas that posed greater predation risk (Kittle et al. 2008). Therefore, understanding how individuals use available habitat can potentially explain how populations persist in dynamic environments.

Although there are several predators of white-tailed deer, coyotes are the main predator of adult white-tailed deer in the Northern Great Plains (Moratz et al. 2018) and are also an important predator of white-tailed deer neonates in the Northern Great Plains (Brinkman et al. 2004; Grovenburg et al. 2011) and throughout their range (Gingery et al. 2018; Kautz et al. 2019; Warbington et al. 2017). Furthermore, coyotes are reported to have substantial impacts on white-tailed deer neonate populations at local scales (Chitwood et al. 2015; Kilgo et al. 2012). However, results on effects of habitat composition and structure on neonate survival is inconsistent

(Chitwood et al. 2015; Gulsby et al. 2017; Kilgo et al. 2014; Michel et al. 2018).

Although general cover types can affect survival, micro-habitat characteristics also can affect where individuals choose to seek cover. Moose (Bowyer et al. 1999), American bison (*Bison bison*; Kaze et al. 2016), and woodland caribou (*Rangifer tarandus*; Leclerc et al. 2012) dams selected parturition sites at greater elevations, likely to increase visibility and avoid predation. Similarly, after the peak of parturition (28 June to 9 July), pronghorn (*Antilocapra americana*) females selected areas with low vegetative biomass, whereas neonate to female ratios were positively correlated with greater vegetative biomass (Christie et al. 2017). This suggests females select areas that maximize detection of approaching predators (Yoakum 2004), while balancing the need for concealment of the neonate (Barrett 1984).

Much research has focused on microhabitat characteristics associated with neonate bed site selection. Black-tailed deer (Bowyer et al. 1998) and pronghorn (Lehman et al. 2009) neonates selected bed sites with increased forb cover and overstory canopy cover while white-tailed deer neonates selected bed sites with greater vertical structure (Grovenburg et al. 2010; Huegel et al. 1986). Conversely, although concealment was important for neonatal elk < 2 weeks old, neonates tended to select for cover that allowed for increased visibility as they aged (Pitman et al. 2014). Roe deer (*Capreolus capreolus*) neonate bed site selection also varied throughout the parturition season with late-born neonates increasing use of agricultural areas compared with their early-born counterparts (Linnell et al. 2004). Although microhabitat characteristics affect site-specific selection for offspring, direct comparisons regarding how these characteristics differ between offspring and their dams are limited.

Our objective was to compare vegetative characteristics found at white-tailed deer parturition sites and neonate bed sites after assessing whether vegetative characteristics of both parturition and neonate bed sites differed from paired random sites. Both dams and neonates likely select sites to reduce predation risk (Lehman et al. 2016; Pitman et al. 2014; Rearden et al. 2011) and increase thermoregulatory efficiency (Grovenburg et al. 2010; Kjellander et al. 2012; Linnell et al. 1995). Therefore, we developed multiple hypotheses (Tables 1 and 2) to assess what vegetative characteristics affected maternal parturition site and neonate bed site selection. Additionally, given the prevalence of row crop agriculture in the Northern Great Plains (Wright and Wimberly 2013), we examined if percent of various cover types found within parturition and bed sites varied throughout the parturition season to assess if use of row crops increased as crops matured and subsequently provided increased cover.

Materials and methods

Study area

We focused neonate capture in a 2652-km^2 area in the central portion of Burleigh County (47.0449° N, 100.5050° W), North Dakota, in a 1492-km^2 area in the southwestern portion of Dunn County (47.2122° N, 102.7260° W), North Dakota, in a 1865-km^2 area in the southwestern portion of Grant County (46.3951° N, 101.5536° W), North Dakota, and in a 1492-km^2 area in the central portion of Perkins County (45.3888° N, 102.3224° W; Fig. 1), South Dakota. Burleigh County, North Dakota, was located within the Northwestern Glaciated Plains Level III Ecoregion while Grant and Dunn counties, North Dakota, and Perkins County, South Dakota, were located in the Northwestern Great Plains Level III Ecoregion (Bryce

Table 1 List of variables included for each of 9 models describing various vegetation characteristics and structure found for 63 neonate bed sites located in Burleigh, Dunn, and Grant Counties, North Dakota, and Perkins County, South Dakota, USA. We captured neonates in Burleigh County, North Dakota, from 20 May to 30 June 2011 and from 23 May to 23 June in Dunn and Grant Counties, North Dakota, and in Perkins County, South Dakota, during 2014 and 2015

Model name	Variable description
Grassland	Percent grassland
Forested	Percent forested
Forb	Percent forbs including alfalfa
Vegetative structure	Understory vegetation height + percent canopy cover
Vegetative overstory	Overstory vegetation height
Vegetative understory	Understory vegetation height
Grassland + structure	Percent grassland + understory vegetation height + percent canopy cover
Forested + structure	Percent forested + understory vegetation height + percent canopy cover
Forb + structure	Percent cropland + understory vegetation height + percent canopy cover

Table 2 List of variables included for each of 4 models describing various vegetation characteristics and structure found for 16 parturition sites located in Burleigh, Dunn, and Grant Counties, North Dakota, and Perkins County, South Dakota, USA. We captured neonates in Burleigh County, North Dakota, from 20 May to 30 June 2011 and from 23 May to 23 June in Dunn and Grant Counties, North Dakota, and in Perkins County, South Dakota, during 2014 and 2015

Model name	Variable description
Grassland	Percent grassland
Forb	Percent forb
Vegetative overstory	Overstory vegetation height
Vegetative understory	Understory vegetation height

Fig. 1 Study area where vegetative characteristics for 53 parturition and 140 white-tailed deer bed sites were measured. **a** Burleigh County, North Dakota. **b** Dunn County, North Dakota. **c** Grant County, North Dakota. **d** Perkins County, South Dakota. We captured neonates in Burleigh County, North Dakota, from 20 May to 30 June 2011 and from 23 May to 23 June in Dunn and Grant Counties, North Dakota, and in Perkins County, South Dakota, during 2014 and 2015
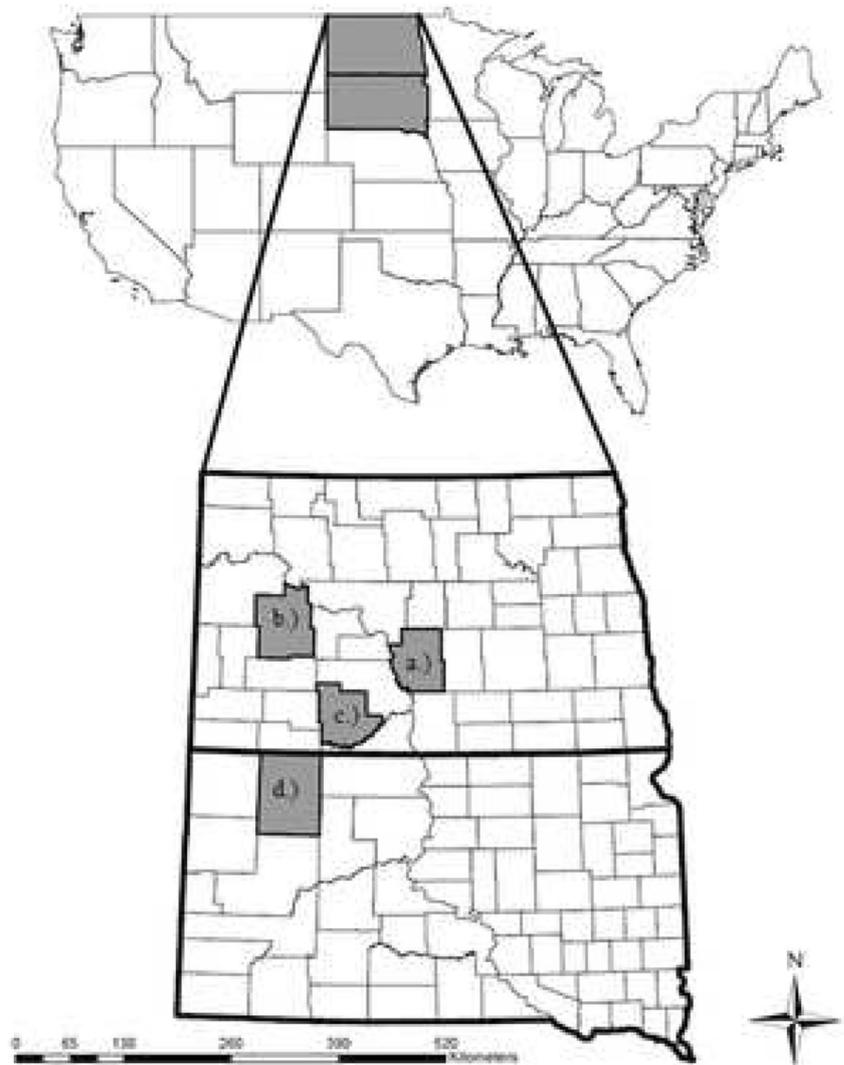
et al. 1998). Grasslands and croplands were the dominant cover types and ranged from 60 to 86% and 11 to 26%, respectively, while forested cover types ranged from 0.01% in Perkins County to 9% in Dunn County (Cropland Data Layer, United States Department of Agriculture (USDA) 2011). Wetlands and water also were prevalent cover types (7%) in Burleigh County but were not prevalent in Dunn, Grant, or Perkins Counties (United States Department of Agriculture (USDA) 2011). Thirty-year mean annual precipitation ranged from 41.2 cm (Grant County) to 44.9 cm (Burleigh and Perkins Counties) and variation in 30-year mean monthly temperature was greatest in Perkins County ranging from − 12.1 to 30.3 °C (North Dakota State Climate Office 2016).

Landscapes in this region were dominated by native mixed grassland prairie species comprised western wheatgrass (*Pascopyrum smithii*), needle-and-thread (*Hesperostipa comata*), green needlegrass (*Nassella viridula*), little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), prairie Junegrass (*Koeleria macrantha*), and reed canarygrass (*Phalaris arundinacea*). Introduced grasses included smooth brome (*Bromus inermis*), orchardgrass (*Dactylis glomerata*), crested wheatgrass (*Agropyron* sp.), timothy (*Phleum pratense*), and Kentucky bluegrass (*Poa pratensis*). Primary harvested crops included corn (*Zea mays*), wheat (*Triticum aestivum*), sunflowers (*Helianthus annuus*), and alfalfa (*Medicago sativa*). Other crops included flaxseed (*Linum usitatissimum*), canola (*Brassica* sp.), soybeans (*Glycine max*), barley (*Hordeum vulgare*), safflower (*Carthamus tinctorius*), oats (*Avena sativa*), and Sudangrass (*Sorghum bicolor*).

Data collection

We captured neonates in Burleigh County, North Dakota, from 20 May to 30 June 2011 and from 23 May to 23 June in Dunn and Grant Counties, North Dakota, and in Perkins County, South Dakota, during 2014 and 2015. We captured adult female (≥ 1.5-year-old) white-tailed deer via helicopter

net guns (Native Range Capture Services, Elko, NV, USA). We then affixed very high frequency (VHF) radio-collars (model M2610B, Advanced Telemetry Systems, Isanti, MN) to individuals and inserted Vaginal Implant Transmitters (Advanced Telemetry Systems, Inc., Isanti, MN, USA; Bowman and Jacobson 1998; Carstensen et al. 2003; Swanson et al. 2008). We also used reproductive female post-partum behavior as an indicator of presence of neonates (Downing and McGinnes 1969; Huegel et al. 1985; White et al. 1972) and then captured neonates by hand or net. We wore latex gloves and stored all radio-collars and other equipment in natural vegetation to minimize scent transfer. We fitted neonates with expandable breakaway radio-collars and monitored individuals daily for the first 30 days using a truck-mounted null-peak antenna system (Brinkman et al. 2002), hand-held Yagi antennas, aerial telemetry, and omnidirectional whip antennas. We determined bed sites to be locations where we opportunistically captured neonates and parturition sites to be locations where we found a VIT. We only captured neonates once. All handling methods followed the American Society of Mammalogists guidelines for mammal care and use (Sikes et al. 2016) and were approved by the South Dakota State University Institutional Animal Care and Use Committee (Approval No. 10-006E and 13-091A).

We completed vegetation assessments at parturition sites and neonate bed sites immediately if neonates flushed upon approach or collected measurements within 39 days if neonates did not flush. We measured all vegetation heights using a modified Robel pole (Robel et al. 1970) with 10-cm increments. The observer was about 4 m from the Robel pole when collecting vegetation data. Vegetation overstory height represented the tallest vegetation marked on the Robel pole, whereas understory vegetation height represented the tallest vegetation where the Robel pole was completely obstructed. We recorded measurements from the center of the parturition or bed site in each cardinal direction and averaged them (by site) to determine height of the vegetation overstory and height of vegetation understory (Robel et al. 1970). We recorded ocular estimations of percent cover using 5% increments for bare ground, forbs (including alfalfa), grass, litter, row crop, shrub, and tree in 24, 1.0-m^2 Daubenmire plots (Daubenmire 1959) spaced at 1-m intervals along four perpendicular transects originating at the center of parturition or bed sites and paired random sites. We estimated tree canopy cover at 6 m north, south, east, and west of parturition and bed sites or paired random sites using a spherical densiometer (Uresk et al. 1999). We followed the methods of Grovenburg et al. (2010) and identified each paired random site within 250 m of its associated parturition or bed site. Locating paired random sites within 250 m of its associated parturition or bed site allowed us to keep random sites within the same cover type. After locating paired random sites in similar cover types (grassland, forested, riparian), we then collected data in the same manner as described above for parturition and bed sites (Grovenburg et al. 2010).

Statistical analysis

Due to logistical constraints that delayed us from measuring vegetation at parturition sites, bed sites, and their respective paired random sites up to 39 days later, we restricted our parturition and bed site selection analyses to sites where we collected vegetation measurements within 14 days of locating sites. Therefore, we assessed if vegetation characteristics varied between parturition and bed sites and their paired random sites using a conditional logistic model and estimated odds ratios using the clogit function in the Survival package in Program R (R Core Team 2016 version 3.3.1; Therneau 2015). The clogit function allows for specific comparisons between capture and paired random sites. We developed nine models describing general cover type, vegetative structure, or a combination of cover type and structure for bed sites (Table 1). We simplified our candidate set to four models describing vegetative structure and composition for parturition sites due to sample size ($n = 16$; Table 2). We then ranked each model using Akaike's Information Criterion corrected for small sample size (AIC_c) and considered models within 2 ΔAIC_c as potentially competing (Burnham and Anderson 2002). We derived AIC_c values, number of parameters, and model weights using the AIC_c and weight functions in the MuMIn package in Program R (Barton 2016). We assessed correlation among explanatory variables using the cor.test function and included multiple variables in a single model when $|r| \leq 0.50$. We used the model.avg. function in the MuMIn package in Program R when necessary to calculate model-averaged coefficients. We considered variables important when their 95% confidence intervals (95% CIs) excluded 0 (Burnham and Anderson 2002; Arnold 2010). We considered odds ratios important when their 95% CIs excluded 1. We present all means ± 1 standard deviation.

Finally, we visually assessed if dam and neonate use of specific cover types varied by quantifying the number of parturition and bed sites that we found in each cover type on a weekly basis throughout the parturition season (day 1 representing the first parturition/bed site found followed by the subsequent 6 days). Although vegetative measurements were delayed, the cover type of each site would not have changed temporally. Therefore, we used our entire dataset for this assessment.

Results

We captured neonates from 20 May to 30 June and collected vegetation data at 34 parturition sites primarily located in grassland (47%; $n = 16$), riparian (26%, $n = 9$), and wooded (18%, $n = 6$) cover types with all other cover types containing $\leq 9\%$ ($n = 3$) of parturition sites. We collected vegetation data at 63 individual neonate bed sites primarily located in grasslands (68%; $n = 43$), followed by riparian (17%; $n = 11$), and wooded (11%; $n = 7$) cover types with all other cover types

containing $\leq 2\%$ ($n = 2$) of bed sites. Explanatory variables were not correlated ($|r| \leq 0.33$).

Given we found most parturition sites in grasslands, we reduced our analysis to include only those parturition sites found in grasslands. In doing so, we observed two competing models that described vegetation characteristics at parturition sites (Table 3). Our top supported model was our vegetative understory model, which carried a majority of model weight ($w_i = 0.64$). Understory vegetation height at parturition sites differed from random sites and had a negative effect ($\beta = -0.168$; 95% CI, -0.325–-0.011, $n = 16$) on parturition site selection such that for every 1-cm decrease in understory vegetation height, probability of a female selecting that site for parturition increased 15.4% (odds ratio = 0.845; 95% CI, 0.722–0.989). Mean understory vegetation height was 22.6 ± 12.7 cm at parturition sites and was 31.8 ± 13.0 cm at random sites. Overstory vegetation height at parturition sites differed from random sites and had a negative effect ($\beta = -0.067$; 95% CI, -0.128–-0.005, $n = 16$) on parturition site selection such that for every 1-cm decrease in overstory vegetation height, probability of a female selecting that site for parturition increased 6.5% (odds ratio = 0.935; 95% CI, 0.880–0.994). Mean overstory vegetation height was 52.9 ± 26.9 cm at parturition sites and was 71.2 ± 16.8 cm at random sites. The likelihood ratio test indicated adequate model fit (vegetative understory model, 9.26, $DF = 1$, $P = 0.002$; vegetative overstory model, 8.01, $DF = 1$, $P = 0.005$).

Although our most parsimonious model describing neonate bed site selection was our vegetative structure model, it carried low model weight ($w_i = 0.31$; Table 4). Our forb + structure model ($w_i = 0.19$) and vegetative understory model ($w_i = 0.14$) also appeared to be competing. The 95% CIs in our top models overlapped 0 for all variables (S1).

Therefore, we calculated the model-averaged coefficients due to model uncertainty (Burnham and Anderson 2002). After model averaging, there was a trend of understory vegetation height ($\beta = 0.025$; 95% CI, -0.005–0.065, $n = 63$) and overstory

vegetation height ($\beta = 0.001$; 95% CI, -0.009–0.034, $n = 63$) displaying a general positive impact on bed site selection. The 95% CIs for all other model-averaged coefficients greatly overlapped 0 (Table 5). Mean understory vegetation height was 36.2 ± 14.0 cm at bed sites and 32.4 ± 16.3 cm at random sites. Mean overstory vegetation height was 72.8 ± 24.5 cm at bed sites and was 69.5 ± 24.6 cm at random sites. The likelihood ratio test indicated adequate model fit for our vegetative structure model (6.96, $DF = 2$, $P = 0.030$) and for our forb + structure model (8.26, $DF = 3$, $P = 0.040$) but not for our vegetative understory model (3.32, $DF = 1$, $P = 0.70$).

We did not detect any trends for variation in cover types used for parturition sites (Fig. 2) and bed sites (Fig. 3) throughout the parturition season as we consistently found parturition and bed sites in grassland and riparian cover types. We did not find any parturition sites in row crop or other cover types.

Discussion

Our understory vegetation height model was our top supported model for parturition site selection with our overstory vegetation height model competing with our top model. Adult female white-tailed deer selected for shorter vegetation than random when selecting parturition sites. Our results support Rearden et al. (2011) who found female elk selected for parturition sites with increased visibility (but see Alldredge et al. 1991, Barrett 1984, Barbknecht et al. 2011, and Lehman et al. 2016 for cases where female ungulates selected parturition sites with increased cover). Regardless, moose (Bowyer et al. 1999), American bison (Kaze et al. 2016), and woodland caribou (Leclerc et al. 2012) selected for parturition sites at higher elevations, likely to increase their

Table 3 Model results for 4 models describing various vegetation characteristics and structure found for 16 parturition sites of adult female white-tailed deer located in Burleigh, Dunn, and Grant Counties, North Dakota, and Perkins County, South Dakota, USA. We captured neonates in Burleigh County, North Dakota, from 20 May to 30 June 2011 and from 23 May to 23 June in Dunn and Grant Counties, North Dakota, and in Perkins County, South Dakota, during 2014 and 2015

Model	ΔAIC_c	w_i	K
Vegetative understory	0.00	0.64	1
Vegetative overstory	1.25	0.34	1
Forb	7.87	0.01	1
Grassland	9.23	0.01	1

Table 4 Model results for 9 models describing various vegetation characteristics and structure found for 63 bed sites of neonate white-tailed deer located in Burleigh, Dunn, and Grant Counties, North Dakota, and Perkins County, South Dakota, USA. We captured neonates in Burleigh County, North Dakota, from 20 May to 30 June 2011 and from 23 May to 23 June in Dunn and Grant Counties, North Dakota, and in Perkins County, South Dakota, during 2014 and 2015

Model	ΔAIC_c	w_i	K
Vegetative structure	0.00	0.31	2
Forb + structure	0.91	0.19	3
Vegetative understory	1.51	0.14	1
Grassland + structure	2.19	0.10	3
Forested + structure	2.25	0.10	4
Forb	3.56	0.05	1
Vegetative overstory	3.58	0.05	1
Grassland	4.58	0.03	1
Forested	5.28	0.02	2

Table 5 Model-averaged beta coefficients and 95% confidence intervals for 63 bed sites of white-tailed deer neonates collected throughout South Dakota and North Dakota, USA. We captured neonates in Burleigh County, North Dakota, from 20 May to 30 June 2011 and from 23 May to 23 June in Dunn and Grant Counties, North Dakota, and in Perkins County, South Dakota, during 2014 and 2015

Variable	Beta	Lower 95% CI	Upper 95% CI
Understory vegetation height	0.025	−0.005	0.065
Percent canopy cover	0.044	−0.018	0.143
Percent forb	0.006	−0.021	0.070
Percent grass	−0.001	−0.040	0.032
Percent forested	−0.023	−0.569	0.189
Percent shrub	−0.005	−0.159	0.080
Overstory vegetation height	0.001	−0.009	0.034

Although we report a general trend of increased vegetation height at neonate bed sites compared with random sites, weak estimates and imprecise confidence intervals preclude us from directly discussing this variation. Nevertheless, several studies report ungulate neonates such as mule deer (Gerlach and Vaughan 1991), elk (Pitman et al. 2014), bighorn sheep (*Ovis canadensis*; Smith et al. 2015), and pronghorn (Barrett 1984; Christie et al. 2017) selected for bed sites with increased concealment. White-tailed deer neonates display fear bradycardia and are relatively immobile within their first 30 days of life (Carl and Robbins 1988; Lent 1974). Therefore, increased understory and overstory vegetation height provides increased cover and visual obstruction from predators potentially decreasing predation risk, though the effects of vegetation at bed sites on neonate survival are inconsistent (Canon and Bryant 1997; Chitwood et al. 2015). Increased vegetative height at neonate bed sites also could potentially help neonates thermoregulate during inclement weather (precipitation events), potentially influencing survival (Grovenburg et al. 2010; Kjellander et al. 2012; Linnell et al. 1995). Grassland was the most common cover type in our study, comprised up to 86% of the landscape, and was the most common cover type in which neonate bed sites were located throughout the parturition season. Concomitantly, fawn survival is generally
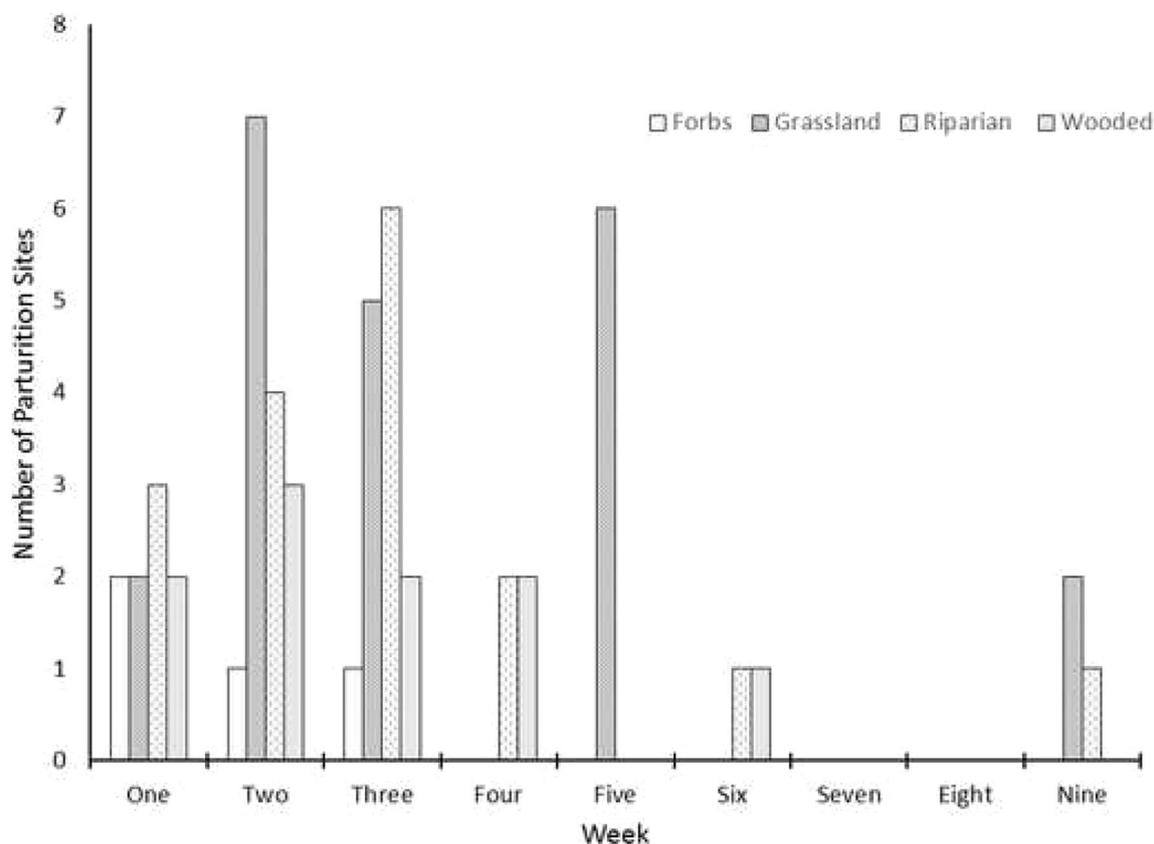
visibility. Therefore, given the magnitude of difference between vegetative heights recorded at parturition sites compared with random sites and the increased probability of a mother selecting a site based on vegetative height, increasing visibility during a birthing event is seemingly an important antipredator defense strategy for white-tailed deer mothers using grassland cover types in the Northern Great Plains.

Fig. 2 Number of parturition sites used by week throughout the parturition season in South Dakota and North Dakota, USA. We located parturition sites from 20 May to 30 June 2011 and from 23 May to 23 June in 2014 and 2015. Parturition sites were not found in either row crop or other cover types

Fig. 3 Number of bed sites used by week throughout the parturition season in South Dakota and North Dakota, USA. We located parturition sites from 20 May to 30 June 2011 and from 23 May to 23 June in 2014 and 2015
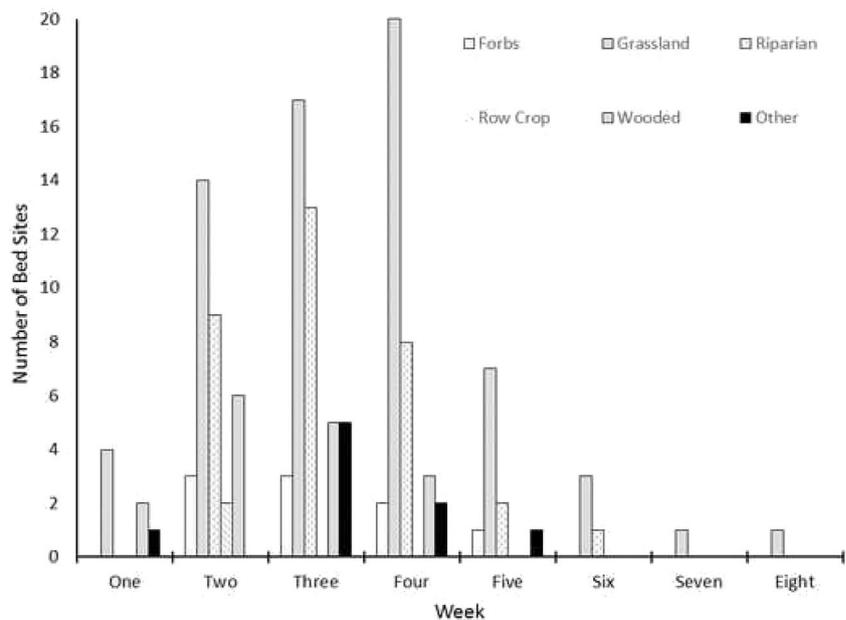
high in the Northern Great Plains (Michel et al. 2018). Given the lack of variation between vegetative structure at neonate bed sites compared with random sites (understory vegetation height = ~ 4-cm difference; overstory vegetation height = ~ 3-cm difference), our results indicate grasslands likely provide the vegetative structure necessary for adequate concealment and thermoregulation that neonates require early in life in the Northern Great Plains.

Neither maternal nor neonate use of cover types varied throughout the parturition season. Although row crops such as corn and soybeans mature throughout the summer and, therefore, provide increased hiding cover as neonates age (Grovenburg et al. 2012a), we found no evidence that white-tailed deer use agricultural crops more than other cover types later in the parturition season. This is likely because grasslands, riparian areas, and forested areas represent permanent cover and provide vegetation with adequate height during the parturition season. Phenology of cool-season grasses also can impact white-tailed deer selection given that 47% of parturition sites and 68% of neonate bed sites were found in grasslands. For example, cool-season grasses grow mostly in early spring and generally complete flowering by 21 June (Leopold and Kriedemann 1975; Weier et al. 1974); we captured all neonates by 30 June. Dams also selected understory vegetation that was about 23 cm tall while neonates selected vegetation that was about 36 cm tall, a height most cool-season plants reach before maturation. Therefore, between growth of cool-season grasses and residual dead plant material, dams and neonates likely had enough permanent cover in grasslands throughout the parturition season while obtaining additional cover from riparian and forested areas.

Our results emphasize the importance of understanding whether habitat requirements vary by life-stage for a species.

For example, previous research has shown that forested areas provide important winter cover for adult white-tailed deer (Grovenburg et al. 2011), whereas white-tailed deer neonate survival decreased with increasing forested cover; potentially because small linear tree plantings on the prairie may serve as ecological traps due to coyote predation (Grovenburg et al. 2012b). Nevertheless, understanding age-specific habitat requirements allows for more specific habitat management, which ultimately encourages vegetative diversity on the landscape and could potentially impact life-history characteristics such as survival for several age-classes.

We recommend maintaining a mosaic of grassland, riparian, and forested cover types in agriculturally dominated landscapes as those cover types contained 92% of parturition sites and 86% of all bed site locations in our study. Furthermore, maintaining an understory vegetation height of about 23 cm for mothers and about 36 cm for neonates while maintaining an overstory vegetation height of about 53 cm for mothers and about 73 cm for neonates should allow for adequate visibility for mothers and adequate concealment for neonates, particularly in grassland cover types. Maintaining this vegetative height will also likely allow mothers to detect predators during parturition events (Rearden et al. 2011) and may assist neonates in avoiding detection by predators (Gerlach and Vaughan 1991; Pitman et al. 2014; Smith et al. 2015). Finally, dam and neonate use of cover types did not vary throughout the parturition season, suggesting white-tailed deer likely do not increase use of agricultural crops throughout the parturition season; however, deer do likely increase their use of row crops later in summer as crops provide increased cover as they mature (Grovenburg et al. 2012a). Regardless, agricultural crops are probably not beneficial in providing cover to white-tailed deer during the parturition season.

Compliance with ethical standards

All handling methods followed the American Society of Mammalogists guidelines for mammal care and use (Sikes et al. 2016) and were approved by the South Dakota State University Institutional Animal Care and Use Committee (Approval No. 10-006E and 13-091A).

Disclaimer Any mention of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the US Government.

Conflict of interest The authors declare that they have no conflict of interest

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