

South Dakota State University

Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

Natural Resource Management Faculty Publications

Department of Natural Resource Management

7-2020

Habitat Selection of White-tailed Deer Fawns and their Dams in the Northern Great Plains

Eric S. Michel

Bailey S. Gullikson

Katherine L. Brackel

Brian A. Schaffer

Jonathan A. Jenks

See next page for additional authors

Follow this and additional works at: https://openprairie.sdstate.edu/nrm_pubs



Part of the [Ecology and Evolutionary Biology Commons](#), and the [Environmental Sciences Commons](#)

Authors

Eric S. Michel, Bailey S. Gullikson, Katherine L. Brackel, Brian A. Schaffer, Jonathan A. Jenks, and William F. Jensen



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

Eric S. Michel^{1,2} · Bailey S. Gullikson¹ · Katherine L. Brackel¹ · Brian A. Schaffer³ · Jonathan A. Jenks¹ · William F. Jensen³

Received: 10 September 2019 / Accepted: 23 June 2020
© The Author(s) 2020

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

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

Communicated by: Dries Kuijper

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s13364-020-00519-6>) contains supplementary material, which is available to authorized users.

✉ Eric S. Michel
eric.michel@state.mn.us

¹ Department of Natural Resource Management, South Dakota State University, Brookings, SD 57007, USA

² Present address: Division of Fish and Wildlife, Minnesota Department of Natural Resources, Farmland and Wildlife Populations Research Group, 35365 800th Avenue, Madelia, MN 56062, USA

³ North Dakota Game and Fish Department, Bismarck, ND 58501, USA

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

Although general cover types can affect survival, microhabitat 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-km² area in the central portion of Burleigh County (47.0449° N, 100.5050° W), North Dakota, in a 1492-km² area in the southwestern portion of Dunn County (47.2122° N, 102.7260° W), North Dakota, in a 1865-km² area in the southwestern portion of Grant County (46.3951° N, 101.5536° W), North Dakota, and in a 1492-km² 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

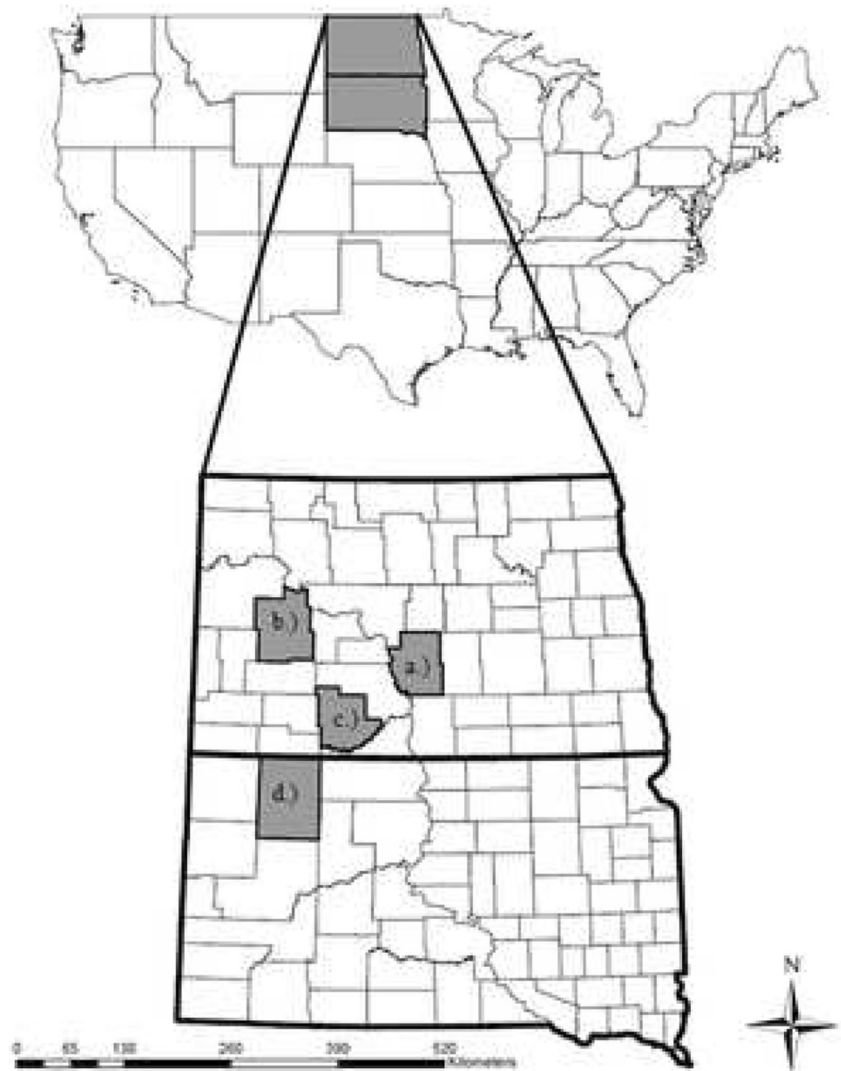
Table 1 List of variables included for each of 9 models describing various vegetation characteristics and structure found for 63 neonate bed sites located in Burleigh, Dunn, and Grant Counties, North Dakota, and Perkins County, South Dakota, USA. We captured neonates in Burleigh County, North Dakota, 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 postpartum 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-m² 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 $2 \Delta AIC_c$ 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

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.

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

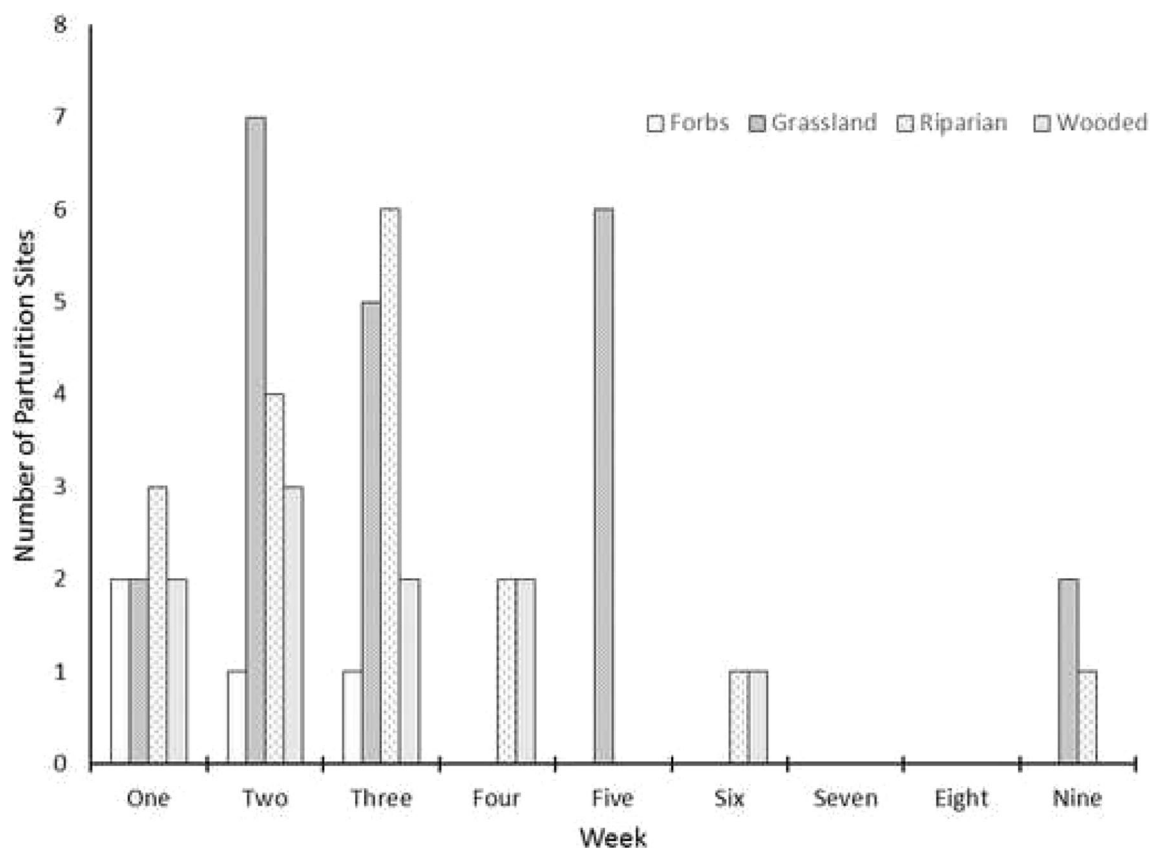
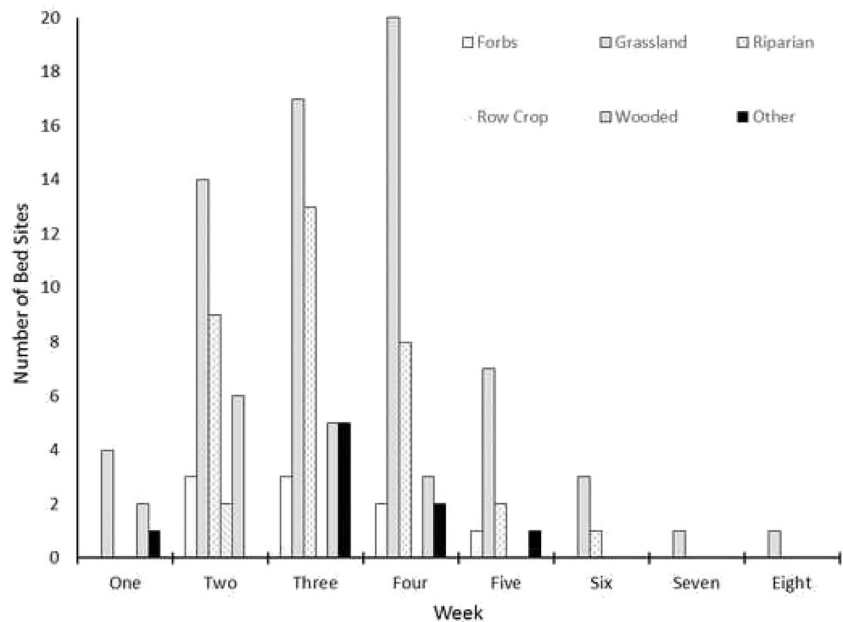


Fig. 2 Number of parturition sites used by week throughout the parturition season in South Dakota and North Dakota, USA. We located parturition sites from 20 May to 30 June 2011 and from 23 May to 23 June in 2014 and 2015. Parturition sites were not found in either row crop or other cover types

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.

Acknowledgments We thank the North Dakota Game and Fish Department, South Dakota Department of Game, Fish and Parks, the Minnesota Department of Natural Resources, the Department of Natural Resource Management at South Dakota State University, and numerous private landowners, graduate students, and technicians for their help and cooperation with this project. We also thank D. Morina, C. Chitwood, M. Festa-Bianchet, and two anonymous reviewers for their helpful comments.

Funding information This work was supported by the Federal Aid to Wildlife Restoration administered through North Dakota Game and Fish Department (Project W-67-R-57, Study No. C-VIII) and through South Dakota Game, Fish, and Parks (Study No. 7555).

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

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Allredge AW, Deblinger RD, Peterson J (1991) Birth and fawn bed site selection by pronghorns in a sagebrush-steppe community. *J Wildl Manag* 55:222–227. <https://doi.org/10.2307/3809143>
- Arnold TW (2010) Uninformative parameters and model selection using Akaike's information criterion. *J Wildl Manag* 74:1175–1178. <https://doi.org/10.1111/j.1937-2817.2010.tb01236.x>
- Barbknecht AE, Fairbanks WS, Rogerson JD, Maichak EJ, Scurlock BM, Meadows LL (2011) Elk parturition site selection at local and landscape scales. *J Wildl Manag* 75:646–654. <https://doi.org/10.1002/jwmg.100>
- Barrett M (1984) Movements, habitat use, and predation on pronghorn fawns in Alberta. *J Wildl Manag* 48:542–550. <https://doi.org/10.2307/3801187>
- Barton K (2016) MuMIn: multi-model inference. R package version 1.15.6. Available from: <https://CRAN.R-project.org/package=MuMIn>. Accessed 30 Jun 2017
- Bowman JL, Jacobson HA (1998) An improved vaginal-implant transmitter for locating white-tailed deer birth sites and fawns. *Wildl Soc Bull* 26:295–298
- Bowyer RT, Kie JG, Van Ballenberghe V (1998) Habitat selection by neonatal black-tailed deer: climate, forage, or risk of predation? *J Mammal* 79:415–425. <https://doi.org/10.2307/1382972>
- Bowyer RT, Van Ballenberghe V, Kie JG, Maier JAK (1999) Birth-site selection by Alaskan moose: maternal strategies for coping with a risky environment. *J Mammal* 80:1070–1083. <https://doi.org/10.2307/1383161>
- Brinkman TJ, DePerno CS, Jenks JA, Haroldson BS, Erb JD (2002) A vehicle-mounted radiotelemetry antenna system design. *Wildl Soc Bull* 30:256–258
- Brinkman TJ, Jenks JA, DePerno CS, Haroldson BS, Osborn RG (2004) Survival of white-tailed deer in an intensively farmed region of Minnesota. *Wildl Soc Bull* 32:726–731. [https://doi.org/10.2193/0091-7648\(2004\)032\[0726:SOWDIA\]2.0.CO;2](https://doi.org/10.2193/0091-7648(2004)032[0726:SOWDIA]2.0.CO;2)
- Bryce SJ, Omernik M, Pater DE, Ulmer M, Schaar J, Freeouf J, Johnson R, Kuck P, Azevedo SH (1998) Ecoregions of North Dakota and South Dakota. (Map poster). U.S. Geological Survey, Jamestown, ND
- Burnham KP, Anderson DR (2002) Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York
- Canon SK, Bryant FC (1997) Bed-site characteristics of pronghorn fawns. *J Wildl Manag* 61:1134–1141. <https://doi.org/10.2307/3802111>
- Carl GR, Robbins CT (1988) The energetic cost of predator avoidance in neonatal ungulates: hiding versus following. *Can J Zool* 66:239–246. <https://doi.org/10.1139/z88-034>
- Carstensen M, DelGiudice GD, Sampson BA (2003) Using doe behavior and vaginal-implant transmitters to capture neonate white-tailed deer in north-central Minnesota. *Wildl Soc Bull* 31:634–641
- Chitwood MC, Lashley MA, Kilgo JC, Pollock KH, Moorman CE, DePerno CS (2015) Do biological and bedsite characteristics influence survival of neonatal white-tailed deer? *PLoS One* 10: e0119070. <https://doi.org/10.1371/journal.pone.0119070>
- Christie KS, Jensen WF, Boyce MS (2017) Pronghorn resource selection and habitat fragmentation in North Dakota. *J Wildl Manag* 81:154–162. <https://doi.org/10.1002/jwmg.21147>
- Ciuti S, Jensen WF, Neilsen SE, Johnson SK, Hosek BM, Boyce MS (2014) An evaluation of historical mule deer fawn recruitment in North Dakota. North Dakota Game and Fish. (Bismark, North Dakota, USA)
- Daubenmire R (1959) A canopy-coverage method of vegetational analysis. *Northwest Sci* 33:43–64
- Downing RL, McGinnes BS (1969) Capturing and marking white-tailed deer fawns. *J Wildl Manag* 33:711–714. <https://doi.org/10.2307/3799399>
- Gerlach TP, Vaughan MR (1991) Mule deer fawn bed site selection on the Pinon. Canyon Maneuver Site, Colorado. *Southwest Nat* 36: 255–258. <https://doi.org/10.2307/3671933>
- Gingery TM, Diefenbach DR, Wallingford BD, Rosenberry CS (2018) Landscape-level patterns in fawn survival across North America. *J Wildl Manag* 82:1003–1013. <https://doi.org/10.1002/jwmg.21456>
- Grovenburg TW, Jacques CN, Klaver RW, Jenks JA (2010) Bed site selection by neonate deer in grassland habitats on the Northern Great Plains. *J Wildl Manag* 74:1250–1256. <https://doi.org/10.1111/j.1937-2817.2010.tb01245.x>
- Grovenburg TW, Jacques CN, Klaver RW, DePerno CS, Brinkman TJ, Swanson CS, Jenks JA (2011) Influence of landscape characteristics on migration strategies of white-tailed deer. *J Mammal* 92:534–543. <https://doi.org/10.1644/09-MAMM-A-407.1>
- Grovenburg TW, Klaver RW, Jenks JA (2012a) Spatial ecology of white-tailed deer fawns in the Northern Great Plains: implications of loss

- of Conservation Reserve Program Grasslands. *J Wildl Manag* 76: 632–644. <https://doi.org/10.1002/jwmg.288>
- Grovenburg TW, Klaver RW, Jenks JA (2012b) Survival of white-tailed deer fawns in the grasslands of the Northern Great Plains. *J Wildl Manag* 76:944–956. <https://doi.org/10.1002/jwmg.339>
- Gulsby WD, Kilgo JC, Vukovich M, Martin JA (2017) Landscape heterogeneity reduces coyote predation on white-tailed deer fawns: landscape characteristics affect fawn predation. *J Wildl Manag* 81: 601–609. <https://doi.org/10.1002/jwmg.21240>
- Hebblewhite M, Merrill EH (2009) Trade-offs between predation risk and forage differ between migrant strategies in a migratory ungulate. *Ecology* 90:2445–2454. <https://doi.org/10.1890/08-2090.1>
- Hebblewhite M, Merrill EH, McDonald TL, Ranta E (2005) Spatial decomposition of predation risk using resource selection functions: an example in a wolf-elk predator-prey system. *Oikos* 111:101–111. <https://doi.org/10.1111/j.0030-1299.2005.13858.x>
- Huegel CN, Dahlgren RB, Gladfelter HL (1985) Use of doe behavior to capture white-tailed deer fawns. *Wildl Soc Bull* 13:287–289
- Huegel CN, Dahlgren RB, Gladfelter HL (1986) Bed-site selection by white-tailed deer fawns in Iowa. *J Wildl Manag* 53:474–480. <https://doi.org/10.2307/3801109>
- Kautz TM, Belant JL, Beyer DE Jr, Strickland BK, Petroelje TR, Sollmann R (2019) Predator densities and white-tailed deer fawn survival. *J Wildl Manag* 83:126–1270. <https://doi.org/10.1002/jwmg.21681>
- Kaze J, Whiting JC, Freman ED, Bate SB, Larsen RT (2016) Birth-site selection and timing of births in American bison: effects of habitat and proximity to anthropogenic features. *Wildl Res* 43:418–428. <https://doi.org/10.1071/WR15205>
- Kilgo JC, Ray HS, Vukovich M, Goode MJ, Ruth C (2012) Predation by coyotes on white-tailed deer neonates in South Carolina. *J Wildl Manag* 76:1420–1430. <https://doi.org/10.1002/jwmg.393>
- Kilgo JC, Vukovich M, Ray HS, Shaw CE, Ruth C (2014) Coyote removal, understory cover, and survival of white-tailed deer neonates. *J Wildl Manag* 78:1261–1271. <https://doi.org/10.1002/jwmg.764>
- Kittle AM, Fryxell JM, Desy GE, Hamr J (2008) The scale-dependent impact of wolf predation risk on resource selection by three sympatric ungulates. *Oecologia* 157:163–175. <https://doi.org/10.1007/s00442-008-1051-9>
- Kjellander P, Svartholm I, Bergvall UA, Jarnemo A (2012) Habitat use, bed-site selection and mortality rate in neonate fallow deer *Dama dama*. *Wildl Biol* 18:280–291. <https://doi.org/10.2981/10-093>
- Leclerc M, Dussault C, St-Laurent MH (2012) Multiscale assessment of the impacts of roads and cutovers on calving site selection in woodland caribou. *For Ecol Manage* 286:59–65. <https://doi.org/10.1016/j.foreco.2012.09.010>
- Lehman CP, Hartland JD, Keller BJ, Millsbaugh JJ, Brundige GC (2009) Bed site selection of fawn pronghorn in Custer State Park, South Dakota. *Prairie Nat* 41:100–109
- Lehman CP, Rumble MA, Rota CT, Bird BJ, Fogarty DT, Millsbaugh JJ (2016) Elk resource selection at parturition sites, Black Hills, South Dakota. *J Wildl Manag* 80:465–478. <https://doi.org/10.1002/jwmg.1017>
- Lent PC (1974) Mother-infant relationships in ungulates. In: Geist V, Walther F (eds) Symposium on the behavior of ungulates and its relation to management. IUCN Publication 24, Morges, pp 14–55
- Leopold AC, Kriedemann PE (1975) Plant growth and development. McGraw-Hill Book Co., New York
- Linnell JDC, Aanes R, Andersen R (1995) Who killed bambi? The role of predation in the neonatal mortality of temperate ungulates. *Wildl Biol* 1:209–223. <https://doi.org/10.2981/wlb.1995.0026>
- Linnell JDC, Nilsen EB, Andersen R (2004) Selection of bed-sites by roe deer *Capreolus capreolus* fawns in an agricultural landscape. *Acta Theriol* 49:103–111. <https://doi.org/10.1007/BF03192512>
- Michel ES, Jenks JA, Kaskie KD, Klaver RW, Jensen WF (2018) Weather and landscape factors affect white-tailed deer neonate survival at ecologically important life stages in the Northern Great Plains. *PLoS One* 13:e0195247. <https://doi.org/10.1371/journal.pone.0195247>
- Moratz KL, Gullikson BS, Michel ES, Jenks JA, Grove DM, Jensen WF (2018) Assessing factors affecting adult female white-tailed deer survival in the Northern Great Plains. *Wildl Res* 45:679–684. <https://doi.org/10.1071/WR18032>
- North Dakota State Climate Office. (2016). Monthly station normal of temperature, precipitation, and heating and cooling degree days 1981–2010. <https://www.ndsu.edu/ndsco/data/30yearaverage/#c343059>. Accessed 12 July 2016.
- Pitman JW, Cain JW III, Liley SG, Gould WR, Quintana NT, Ballard WB (2014) Post-parturition habitat selection by elk calves and adult female elk in New Mexico. *J Wildl Manag* 78:1216–1227. <https://doi.org/10.1002/jwmg.776>
- R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. (2016). <https://www.R-project.org/>. Accessed 30 June 2017.
- Rearden SN, Anthony RG, Johnson BK (2011) Birth-site selection and predation risk of Rocky Mountain elk. *J Mammal* 92:1118–1126. <https://doi.org/10.1644/09-MAMM-A-019A.1>
- Robel RJ, Briggs JN, Dayton AD, Hulbert LC (1970) Relationships between visual obstruction measurements and weight of grassland vegetation. *J Range Manag* 23:295–297. <https://doi.org/10.2307/3896225>
- Sikes RS, the Animal Care, Use Committee of the American Society of Mammalogists (2016) 2016 Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. *J Mammal* 97:663–688. <https://doi.org/10.1093/jmammal/gyw078>
- Smith JB, Grovenburg TW, Jenks JA (2015) Parturition and bed site selection of bighorn sheep at local and landscape scales. *J Wildl Manag* 79:393–401. <https://doi.org/10.1002/jwmg.843>
- Swanson CC, Jenks JA, DePerno CS, Klaver RW, Osborn RG, Tardiff JA (2008) Does the use of vaginal-implant transmitters affect neonate survival rate of white-tailed deer *Odocoileus virginianus*. *Wildl Biol* 14:272–279. [https://doi.org/10.2981/0909-6396\(2008\)14\[272:DTUOVT\]2.CO;2](https://doi.org/10.2981/0909-6396(2008)14[272:DTUOVT]2.CO;2)
- Therneau T (2015) A package for the survival analysis in S. Version 2.38. <https://cran.r-project.org/package=survival>. Accessed 30 June 2017
- United States Department of Agriculture (USDA) (2011) USDA, National Agricultural Statistics Service (NASS), Cropland Data Layer. USDA, NASS Marketing and Information Services Office, Washington, D.C.
- Uresk DW, Benson TA, Severson KE, Benkobi L (1999) Characteristics of white-tailed deer fawn beds, Black Hills, South Dakota. *Great Basin Nat* 59:348–354
- Warbington CH, Van Deelen TR, Norton AS, Stenglein JL, Storm DJ, Martin KJ (2017) Cause-specific neonatal mortality of white-tailed deer in Wisconsin, USA. *J Wildl Manag* 81:824–833. <https://doi.org/10.1002/jwmg.21260>
- Weier TE, Stocking CR, Barbour MG (1974) Botany: an introduction to plant biology. John Wiley and Sons, New York
- White M, Knowlton FF, Glazener WC (1972) Effects of dam-newborn fawn behavior on capture and mortality. *J Wildl Manag* 36:897–906. <https://doi.org/10.2307/3799446>
- Wright CK, Wimberly MC (2013) Recent land use change in the Western Corn Belt threatens grasslands and wetlands. *Proc Natl Acad Sci* 110:4134–4139. <https://doi.org/10.1073/pnas.1215404110>
- Yoakum JD (2004) Habitat characteristic and requirements. In: Yoakum JD (ed) O’Gara BW. Pronghorn ecology and management University Press of Colorado, Colorado, pp 409–446

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.