

Resource Selection by Parturient and Post-parturient White-tailed Deer and their Fawns

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Abstract: Resource selection by female white-tailed deer (*Odocoileus virginianus*) and their offspring during the fawning season can influence survival and recruitment. The selection process in females is thought to represent the balancing of often competing demands to minimize predation risk and maximize resource availability to support the energetic demands of lactation. We used a distance-based approach to examine selection of fawn-rearing areas and locations within fawning areas for 20 radio-instrumented female white-tailed deer on Tensas River National Wildlife Refuge, Louisiana. We also examined selection of vegetative attributes at parturition sites ($n=20$) and fawn bed sites ($n=106$). Females selected fawn-rearing areas nearer to agriculture than expected given their home ranges, but within their fawn-rearing areas, females were located farther from agriculture and reforestation than expected. Parturition sites and fawn bed sites had greater visual obstruction (VO) than random sites. With every 20% increase in VO, a site was 2.55 or 1.66 times more likely to be used as a parturition or bed site, respectively. Avoiding agricultural and CRP reforestation areas and selecting sites with more concealment cover suggests that both females and fawns selected areas that reduce predation risk to the fawn.

Key words: habitat, *Odocoileus virginianus*, predation risk, resource selection

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In most large herbivores, juvenile survival is low and is also variable relative to adult survival; therefore, it is often important to population dynamics (Gaillard et al. 1998, 2000; Eberhardt 2002). Resource selection during fawning and subsequent selection of fawn rearing areas can influence survival and recruitment (Van Moorter et al. 2009). Resource selection decisions are generally related to habitat attributes that influence fitness (Van Horne 1983, Kristan 2003). Consequently, there is interest in understanding the spatial ecology of ungulates during reproduction to provide habitat management recommendations to improve recruitment. Resource selection during late gestation, parturition, and lactation must balance predation risk and the energetic demands of lactation (Bowyer et al. 1998, Kjellander et al. 2004, Bongi et al. 2008, Panzacchi et al. 2010). Resource selection is a hierarchical process (Johnson 1980) and understanding selection at multiple scales can illuminate the complex balancing of competing demands of food and safety.

Ungulates exhibit either hider or follower strategies after parturition to minimize predation during early life (Carl and Robbins

1988). Mothers of neonates that are hidiers often stay within close proximity to aid in defense from predators and to allow frequent feedings during the hiding phase. Due to limited mobility of neonates, parturient and post-parturient mothers greatly restrict the size of their home range and actively defend territories from conspecifics during parturition and lactation [Alpine ibex (*Capra ibex*), Grignolio et al. 2007; fallow deer (*Dama dama*), Ciuti et al. 2006; white-tailed deer (*Odocoileus virginianus*), Ozoga et al. 1982, Schwede et al. 1993]. Selection of fawn-rearing area has implications for forage availability and hiding cover during early lactation at the peak of both energetic demands of reproduction and predation on neonates.

Within the maternal home range, fawns should select bed sites that minimize risk of detection by predators and facilitate thermoregulation. Cover and visual obstruction are important predictors for bed site selection in numerous hiding ungulates [white-tailed deer, Huegel et al. 1986, Chitwood et al. 2015b; pronghorn (*Antilocapra americana*), Canon and Bryant 1997; roe deer (*Capreolus*

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capreolus), Linnell et al. 1999]. Cover at bed sites provides concealment from predators and protection from climatic conditions. In colder environments, hypothermia can be an important source of mortality for neonatal ungulates [roe deer, Andersen and Linnell 1998; Mongolian gazelle (*Procapra gutturosa*), Olson et al. 2005; domestic sheep (*Ovis aries*), Nowak and Poindron 2006], and in these systems bed sites must provide thermal insulation. In warmer environments, shade from solar radiation can be an important predictor for bed sites (Huegel et al. 1986).

White-tailed deer populations in the eastern United States have experienced changing predator communities in recent decades. Predators such as coyotes (*Canis latrans*) and black bears (*Ursus americanus*) can be important sources of mortality for fawns (Vreeland et al. 2004, Kilgo et al. 2012, Nelson et al. 2015, Conner et al. 2016), and low fawn survival can drive population declines (Chitwood et al. 2015a). Spatial ecology of reproducing female deer can influence reproductive success (Van Moorter et al. 2009, Shuman et al. 2017), and consequently there is interest in resource selection by females during fawn rearing. Therefore, we studied the resource selection of fawning in white-tailed deer in a system with coyotes, bobcats (*Lynx rufus*), and black bears. We examined selection of maternal home ranges, locations of fawn-rearing areas within maternal ranges, parturition sites, and fawn bed sites.

Methods

Study Site

Tensas River National Wildlife Refuge (TRNWR) is located in northeast Louisiana in the western floodplain of the Mississippi River and encompasses mature bottomland hardwood stands, forest stands established between 1987 and 2002, bald cypress (*Taxodium distichum*)/tupelo (*Nyssa aquatica*) swamps, and oxbow lakes. Forest stands consisted of water oak (*Quercus nigra*), willow oak (*Q. phellos*), hickory (*Carya* spp.), sweetgum (*Liquidambar styraciflua*), elm (*Ulmus* spp.), ash (*Fraxinus* spp.), and sugarberry (*Celtis laevigata*) with an understory of dwarf palmetto (*Sabal minor*), blackberry (*Rubus* spp.), poison ivy (*Toxicodendron radicans*), trumpet creeper (*Campsis radicans*), and greenbrier (*Smilax* spp.). The study area was confined to approximately 8000 ha in the northern section of TRNWR. Habitat management within the study area consisted of timber harvesting operations, planting food plots with crops such as soy beans (*Glycine max*) and milo (*Sorghum* sp.), and seasonally flooding moist soil areas and impoundments primarily for waterfowl.

Capture and Monitoring of Adult Females

We captured adult females (≥ 1.5 years) from January to April 2013 and 2014 using drop nets, rocket nets, and tranquilizer dart

guns (Daninject, Børkop, Denmark). We anesthetized deer captured under nets using an intramuscular injection of ketamine hydrochloride (3.5 mg kg⁻¹; Congaree Veterinary Pharmacy, Cayce, South Carolina) and xylazine hydrochloride (2.5 mg kg⁻¹; Congaree Veterinary Pharmacy). We anesthetized deer captured with dart guns using Telazol (250 mg; Fort Dodge Animal Health, Fort Dodge, Iowa) and xylazine hydrochloride (225 mg; Congaree Veterinary Pharmacy) in 1-ml Pneu-Dart transmitter darts (Pneu-Dart Inc., Williamsport, Pennsylvania). Immediately following injection, we blindfolded deer, placed them in a sternal position on an insulated mat, and covered them with a blanket, as a side effect of the anesthesia is the inability for the individual to thermoregulate. We applied ophthalmic ointment and monitored vital signs at 10-minute intervals. We radio-collared (Model 2510B, Advanced Telemetry Systems, Isanti, Minnesota), ear-tagged, and implanted each female with a temperature-activated vaginal implant transmitter (VIT; 2013; Model M3930, Advanced Telemetry Systems) or a temperature- and light-activated VIT (2014; M3930L, Advanced Telemetry Systems; Cherry et al. 2013) to notify us of a birthing event. Following instrumentation, we antagonized the xylazine hydrochloride with tolazoline hydrochloride (150 mg intravenous and 150 mg intramuscular; Congaree Veterinary Pharmacy) and monitored the deer until ambulatory. The University of Georgia Institutional Animal Care and Use Committee, permit #A2012 06-006-Y3-A2, approved capture and handling protocol. To identify parturition events and to facilitate fawn capture, we monitored adults once a day until the first collared female gave birth. After the first parturition event, we monitored females every 8 h until the last collared female gave birth. We located adult females weekly via triangulation from 1 April of their capture year until the following April but located them three times a week from 1 May–31 August of their capture year.

Parturition Site and Fawn Bed Site Identification

In the event of a VIT expulsion, we tracked to the parturition site using a 3-element yagi antenna and receiver. We marked the parturition site with a handheld GPS and flagged the location. Captured fawns were sexed, weighed, and fitted with elastic, break-away collars with a VHF transmitter (M4210; Advanced Telemetry Systems, Isanti, Minnesota) with a 4-h delay motion-sensitive mortality switch. We located fawn bed sites three times per week for up to 4 weeks via radio-telemetry. To minimize disturbance, we approached fawns quietly and attempted to mark bed sites without flushing fawns. We marked the location we first observed the fawn visually with a handheld GPS and flagged the bed site location. We ceased collecting bed site locations once a fawn began to flush before its bed site location could be visualized.

Resource Selection

Distributions of bedded fawns across a landscape are the result of a hierarchical process of resource selection by the female and fawn. We measured four aspects of resource selection associated with fawning in a use-availability framework: (1) Selection of the fawn-rearing area within the annual home range; (2) resource selection within the fawn-rearing area; (3) selection of parturition sites within fawn-rearing areas; (4) selection of fawn bed sites. We assumed females selected fawn-rearing areas from their home ranges (Cherry et al. 2017a), and therefore we estimated the fawn-rearing area using a 90% minimum convex polygon (MCP) including all telemetry locations collected during the six weeks prior to and following parturition (Schwede et al. 1993, Bertrand et al. 1996). We defined the female's annual home range using a 90% MCP including all locations for each given individual. To examine selection within the fawn-rearing area, we compared telemetry locations (i.e., observed) to the fawning area 90% MCP. To examine selection of parturition sites, we compared attributes associated with parturition sites and random locations selected within 100 m. Finally, we compared bed site locations to random locations within 100 m.

Selection of and within fawn-rearing areas.—We investigated selection of fawn-rearing areas within the maternal home range and resource selection within fawn-rearing areas in a use-availability framework (Manly et al. 2002). For each deer, we constructed a 90% MCP using all maternal locations with an error ellipse of ≤ 2 ha and used these polygons to represent available habitat for fawn rearing. We assigned deer-specific fawn-rearing seasons by identifying the 84-day window centered around the parturition event. This included both the pre-partum phase when females establish exclusive territories and the early lactation phase. We used locations from the deer-specific fawn-rearing season to model the fawn-rearing area using a 90% MCP.

We examined resource selection using a systematic sampling approach for Euclidean distance analysis of habitat selection (Conner and Plowman 2001, Conner et al. 2003, Benson 2013). We created a distance raster layer with 10×10 m cells for each habitat feature using the Euclidean Distance tool in ArcMAP 10.2. For each fawn-rearing season, we developed raster layers representing mature bottomland hardwood, agriculture, reforestation, and roads based on interpretation of National Agriculture Imagery Program (NAIP) aerial imagery taken in 2013 and TRNWR forestry records (N.J. Renick, U.S. Fish and Wildlife Service, unpublished data). We calculated the distance from each deer location to each habitat feature by plotting locations on the distance raster layers and extracting the values from the raster layers to the point locations. We

used values from all raster cells within each MCP (i.e., fawn-rearing areas and composite home ranges) to calculate mean distance to each habitat feature within the annual home range and fawn-rearing area for each deer. We then calculated a distance ratio (mean observed distance/mean expected distance) for each deer at both orders of selection. We used the observed mean distance within the fawn-rearing area divided by the mean distances in the home range to define selection of a fawn-rearing area for each deer. For selection within the fawn-rearing area, we used the mean observed distances from the deer locations divided by the mean distances within the fawn-rearing area. A distance ratio < 1.0 indicated the deer was closer than expected to that habitat type (i.e., selection), whereas a distance ratio > 1.0 indicated the deer was farther than expected from a given habitat type (i.e., avoidance; Conner and Plowman 2001, Conner et al. 2003, Benson 2013).

We used a multivariate Hotelling's *t*-test to test the hypothesis that observed distances to habitats did not differ from expected distances using deer as the experimental unit (Conner and Plowman 2001, Conner et al. 2003). We investigated significant results from the multivariate test using univariate *t*-tests on each habitat distance ratio to identify which distance ratios differed from 1.0. We created a ranking matrix using paired *t*-tests between each combination of habitat features to rank habitat types in order of preference for both selection of fawn-rearing areas within the maternal home range and resource use within the fawn-rearing area (Conner and Plowman 2001, Conner et al. 2003, Benson 2013).

Selection of birth sites and fawn bed sites.—We compared habitat attributes at parturition sites and bed sites to random locations. We identified random locations by tracking a randomly-generated distance between 20–100 m in a randomly-generated direction from a subset of parturition and bed sites. When sites were in close proximity, we did not sample a random location for each used location. The habitat was relatively homogeneous within habitat types and not heavily fragmented; therefore, we felt that we were able to adequately characterize the habitat attributes of the area surrounding clusters of used locations with a single random point. Because birth and bed sites for each female and her offspring were in close proximity, we used one set of random locations for analyses of both the birth and bed sites. At each used and random location, we used a Nudds board to estimate visual obstruction (VO; Nudds 1977). From 15 m in each cardinal direction, we assigned a score of 1–5 (with 1 being 0–20% VO and 5 representing 80%–100% obstruction) to each of six 0.5-m vertical sections of the 1-m Nudds board. We averaged the score for each direction to provide an index of VO at 0–0.5 m and 0.5–1.0 m. We estimated ground cover at the site and 15 m in each cardinal direction using a 1×1 -m Daubenmire frame to determine percentages of woody,

grass, vine, herbaceous, debris, or bare cover (Daubenmire 1959). We summed the percentage of all non-bare ground cover at each location and calculated the average percent ground cover across all five locations to provide an index of ground cover at the site. We measured canopy cover using a spherical densiometer (Geographic Resource Solutions, Arcata, California) from 0.5 m above ground to represent solar interception at the height of a bedded fawn. We measured basal area (m² ha⁻¹) using a 10-factor prism. In areas of reforestation where trees were <10.16 cm in diameter, we conducted stem counts out to a 15-m radius.

We fit a series of generalized linear mixed models (GLMM) with a logit link function predicting the probability that a site would be used as a bed site treating the individual deer specific intercept as a random effect. We fit models including all possible combinations of the explanatory variables, visual obstruction (VO), ground cover (GC), thermal refugia (TR), stem counts (SC), and basal area (BA). We treated GC, TR, SC, and BA as continuous variables and VO as a categorical variable. We excluded correlated predictor variables from the analysis if $r > 0.60$ (Barbknecht et al. 2011). Visual obstruction at 1.0 m and 0.5 m were correlated at both parturition and fawn bed sites; therefore, we only included VO at 0.5 m as this level most directly related to concealment cover for a bedded parturient female or fawn. We tested our global model for goodness-of-fit using the Hosmer-Lemeshow goodness-of-fit test (Hosmer and Lemeshow 2000) and considered models with a ΔAIC score of <2 to be our best competing models (Burnham and Anderson 2000). We used parameter estimates derived from conditional model averaging and considered variables with 85% confidence intervals that did not contain zero as informative parameters (Arnold 2010). All statistical analyses were performed in R 3.2.4 (R Core Team 2010).

Results

Selection of and within Fawn-rearing Areas

We were able to identify parturition events for 36 females and included 20 females in our analysis for selection. We excluded females that had <25 locations during any season, and because resource selection cannot be examined when multiple habitat types are not available for selection within the female’s home range, we excluded females with home ranges that did not include ≥ 3 habitat types. Selection of ($t_{4,33} = 7.848, P \leq 0.001$) and within ($t_{4,35} = 3.05, P = 0.02$) fawn-rearing areas was non-random. Females selected fawn-rearing areas nearer to agriculture than was expected given availability within their annual home ranges ($t_{19} = -3.524, P = 0.002$; Table 1). However, within the fawn-rearing area females were found farther than would be expected from agriculture ($t_{19} = 2.715, P = 0.014$) and reforestation ($t_{19} = 2.129, P = 0.047$).

Parturition Site Selection

We developed GLMMs with the response variable being site type [i.e., birth ($n = 20$) or random ($n = 53$)] to estimate the effects of vegetation attributes on the probability of site being used a parturition site. We compared 16 models predicting parturition sites as a function of additive and linear combinations of VO, GC, TR, BA, and SC, including a null model and a global model. Hosmer-Lemeshow goodness-of-fit tests indicated acceptable fit for the global model ($\chi^2 = 2.563, P = 0.959$). Competitive models included VO, GC, and BA, but only VO was an informative parameter (Tables 2, 3). The probability of a site being used as a parturition site

Table 1. Results of univariate *t*-tests for three available habitat types and roads for parturient and post-parturient female white-tailed deer at the Tensas River National Wildlife Refuge, Tallulah, Louisiana, 2013–2014.

Order of selection	Habitat	Selection ratio	<i>t</i>	<i>P</i>	Conclusion
2nd	Agriculture	0.81	-3.524	0.002	Selected
	Reforestation	0.96	-0.535	0.599	Not selected
	Mature	1.07	0.587	0.564	Not selected
	Roads	1.08	1.803	0.087	Not selected
3rd	Agriculture	1.14	2.715	0.014	Avoided
	Reforestation	1.16	2.129	0.047	Avoided
	Mature	1.26	2.069	0.052	Not selected
	Roads	1.01	0.314	0.757	Not selected

Table 2. Microhabitat variable combinations used in generalized linear mixed models to predict probability of a site being used as a parturition site at the Tensas River National Wildlife Refuge, Tallulah, Louisiana, 2013–2014. We compared models using Akaike’s Information Criterion corrected for small sample size (AIC_c) and ranked models based on relative differences to the top model (ΔAIC_c).

Model covariates ^a	<i>k</i> ^b	ΔAIC_c	<i>w</i> _i ^c	Cumulative weight	LL
VO	3	0 ^d	0.37	0.37	-40.54
VO + GC	4	1.78	0.15	0.52	-40.31
VO + BA	4	1.93	0.14	0.66	-40.38
VO + TR	4	2.06	0.13	0.79	-40.45
VO + BA + TR	5	3.66	0.06	0.85	-40.1
VO + BA + GC	5	3.70	0.06	0.91	-40.12
VO + GC + TR	5	4.05	0.05	0.96	-40.3
VO + BA + GC + TR	6	5.81	0.02	0.98	-39.99
Null model	2	7.52	0.01	0.99	-45.38
BA	3	8.66	0	0.99	-44.87
GC	3	9.06	0	0.99	-45.07
TR	3	9.24	0	0.99	-45.16
BA + GC	4	10.47	0	0.99	-44.65
BA + TR	4	10.83	0	0.99	-44.84
GC + TR	4	11.17	0	0.99	-45
BA + GC + TR	5	12.76	0	0.99	-44.65

a. VO = Visual Obstruction, GC = Ground Cover, BA = Basal Area, TR = Thermal Refugia
 b. Number of variables
 c. Akaike weight
 d. AIC_c of the top model = 87.41

Table 3. Parameter estimates, unconditional standard errors, and 85% confidence intervals for microhabitat variables found in approximating models of parturition sites at the Tensas River National Wildlife Refuge, Tallulah, Louisiana, 2013–2014.

Variable	Estimate	SE	Lower 85% CI	Upper 85% CI
Visual obstruction	0.912	0.366	0.386	1.439
Ground cover	-0.002	0.008	-0.014	0.010
Basal area	-0.001	0.005	-0.008	0.006

Table 4. Microhabitat variable combinations used in generalized linear mixed models to predict probability of a site being used as a fawn bed site at the Tensas River National Wildlife Refuge, Tallulah, Louisiana, 2013–2014. We compared models using Akaike's Information Criterion corrected for small sample size (AIC_c) and ranked models based on relative differences to the top model (ΔAIC_c).

Model covariates ^a	k^b	ΔAIC_c^c	w_i^c	Cumulative weight	LL
VO	3	0.00 ^d	0.16	0.16	-94.08
VO+BA	4	0.69	0.12	0.28	-93.37
VO+BA+SC	5	0.70	0.12	0.40	-92.31
VO+BA+TR	5	0.72	0.11	0.51	-92.32
VO+GC	4	1.04	0.10	0.61	-93.55
VO+BA+GC	5	1.14	0.09	0.70	-92.53
VO+BA+SC+TR	6	1.37	0.08	0.78	-91.56
VO+TR	4	1.44	0.08	0.86	-93.74
VO+SCL	4	1.63	0.07	0.93	-93.84
VO+BA+SC+GC	6	1.77	0.07	1.00	-91.76

a. VO = Visual Obstruction, BA = Basal Area, SC = Stem Count (>4" DBH), TR = Thermal Refugia, GC = Ground Cover

b. Number of variables

c. Akaike weight

d. AIC_c of the top model = 194.31

Table 5. Parameter estimates, unconditional standard errors, and 85% confidence intervals for microhabitat variables found in approximating models of fawn bed sites at the Tensas River National Wildlife Refuge, Tallulah, Louisiana, 2016.

Variable	Estimate	SE	Lower 85% CI	Upper 85% CI
Visual obstruction	0.509	-0.220	0.192	0.825
Basal area	-0.005	-0.006	-0.004	0.014
Stem count (<4" DBH)	0.008	-0.016	-0.032	0.016
Thermal refugia	-0.003	-0.007	-0.007	0.014
Ground cover	-0.003	-0.008	-0.008	0.015

increased with VO. The odds of a site being used for a parturition site were 2.55 times more likely with every unit (1–5, representing 20% intervals) increase in VO.

Bed site selection

We included 33 fawns in our analysis of bed site selection. We developed GLMMs with the response variable being site type [i.e., bed ($n=106$) or random ($n=53$)] to estimate effects of vegetation attributes on the probability of a site being used as a bed site. We compared 10 models predicting parturition sites as a function of additive and linear combinations of VO, GC, TR, BA, and SC, including a null and global model. Hosmer-Lemeshow goodness-

of-fit tests indicated acceptable fit for the global model ($\chi^2=2.563$, $P=0.959$). Competitive models included VO, GC, ST, TR, and BA, but only VO was an informative parameter (Tables 4, 5). The probability of a site being used as bed site increased with VO. The odds of a site being used for a bed site were 1.66 times more likely with every unit (1–5, representing 20% intervals) increase in VO.

Discussion

Females selected fawn-rearing areas with abundant agriculture but avoided using agriculture and reforestation within the areas. Because resource selection can vary among different scales when there are trade-offs associated with selection of different resources (Myerud et al. 1999), this selection may indicate that females were attempting to balance food availability and predation risk. Although agriculture and reforestation can provide abundant forage, these areas also are preferred habitats for fawn predators such as bobcats (Rolley and Warde 1985, Litvaitis et al. 1986), coyotes (Schreengost et al. 2008, Boisjoly et al. 2010), and black bears (Benson and Chamberlain 2007). In a concurrent study, survival of fawns on TRNWR decreased with proximity to both agriculture and young reforestation (planted 2000–2009; Shuman et al. 2017). Because these habitats are riskier for fawns, females may be avoiding these habitats to increase fawn survival.

Predation tends to affect resource selection at larger scales compared to foraging considerations (Anderson et al. 2005, Fortin et al. 2004). Although we found that females selected fawn-rearing areas near agriculture, they avoided agriculture within the fawn-rearing area. Thus, contrary to previous studies (Rettie and Messier 2000, Fortin et al. 2004), our results suggest deer resource selection was based on forage at the broad scale (selection of the fawn-rearing area) and predation risk at finer scales (selection within the fawn rearing area). Our results are similar to Cherry et al. (2017a), who reported that females selected fawn-rearing areas nearer to agriculture than expected. However, within the fawn-rearing area, females in that study neither selected nor avoided agriculture.

Because we excluded females that had a more homogenous home range (≤ 2 habitat types) based on the requirements of the resource selection analyses, we acknowledge that our results are scale-dependent and must be interpreted in light of the resolution of our habitat classification. Females that did not have access to multiple habitat types may have selected habitats at a resolution we were unable to assess. For example, for a female with a home range entirely encompassed in mature hardwoods, there may have been attributes of that stand that were selected or avoided; however, our land cover data were insufficient to detect those processes. Despite this, our data do suggest that for females that had multiple habitat types to choose from, resource selection was non-random.

Our results also indicate that females and fawns selected birth site and bed site locations with greater visual obstruction than at random sites. This is consistent with many studies that have suggested that bed site selection by fawns is largely a response to predator pressure (Canon et al. 1997, Van Moorter et al. 2009). Although some studies have documented selection of bed sites based on the thermal environment or availability of forage rather than predator avoidance (Bowyer et al. 1998, Van Moorter et al. 2009, Kjellander et al. 2012), most have occurred in areas with low predator pressure. TRNWR has a high number of predator species with three sympatric fawn predators: coyotes, bobcats, and black bears, and fawns on TRNWR experience high rates of predation with 64% of fawns being depredated in the first 12 weeks of life (Shuman et al. 2017). Selection of birth sites and bed sites with abundant vegetative cover can reduce risk of predation by providing concealment and inhibiting air flow, thereby diminishing detection by predators that rely on olfactory cues (Wells and Lehner 1978). For example, several studies have documented that coyotes were more efficient foragers (Gese et al. 1996, Richer et al. 2002) and occurred at greater abundances (Cherry et al. 2017b) in open habitats than forested area, and that coyote predation on fawns was greater in areas with lower amounts of vegetative cover (Carroll and Brown 1977, Nelson and Woolf 1987, Piccolo et al. 2010, Hasapes and Comer 2017).

Habitat selection is a function of selective pressures over evolutionary time scales and thus should be associated with habitat attributes that maximize fitness. Our results support habitat management recommendations that result in abundant concealment cover. However, the relationship between concealment cover and fawn survival appears context dependent. In systems where coyotes are the primary fawn predator, predation decreases with increasing concealment cover (Carroll and Brown 1977, Nelson and Woolf 1987, Piccolo et al. 2010); although there have also been reports of no effect of vegetative attributes on early fawn survival (Kilgo et al. 2014, Chitwood et al. 2015b). In contrast, a North Carolina study suggested that selection by fawns for greater concealment cover resulted in increased probability of coyote predation (Chitwood et al. 2017). Likely the importance of concealment cover is dependent on landscape context; when areas with concealment cover are limited and occur in small patches, predators can cue on those features. Thus, habitat management actions that provide abundant concealment cover in large patches (fallow fields, timber stand improvements), would be preferable over smaller patches of concealment cover (i.e., field borders or unburned drains). Clearly additional studies in a variety of systems are necessary to clarify the link between habitat selection and fawn survival and to generate ubiquitous habitat management recommendations.

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