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Microhabitat Selection by Bobcats in the Badlands and Black Hills of South Dakota, USA: A Comparison of Prairie and Forested Habitats

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ABSTRACT An understanding of habitat selection is important for management of wildlife species. Although bobcat (*Lynx rufus*) resource selection has been addressed in many regions of the United States, little work has been conducted in the Northern Great Plains. From 2006–2008 we captured and radiocollared 20 bobcats in the Badlands (n = 10) and Black Hills (n = 10) regions of South Dakota. During the summers of 2008 and 2009 we collected habitat measurements at 349 (176 Badlands, 176 Black Hills) bobcat locations and 321 (148 Badlands, 173 Black Hills) random sites. Microhabitat characteristics at bobcat use sites varied with region ($P < 0.001$) and sex of bobcat ($P < 0.001$). Percent slope, shrub, low cover, medium cover, and total cover were greater ($P \leq 0.017$) at bobcat locations in the Black Hills than in the Badlands whereas distance to drainage was greater ($P < 0.001$) at locations in the Badlands than in the Black Hills. In the Badlands, male bobcat locations were closer ($P \leq 0.002$) to prairie dog towns and drainages and had greater ($P < 0.05$) percent forbs and forb height than random sites, whereas females were closer to badland formations ($P < 0.001$) than random sites. In the Black Hills, male locations were at greater elevation ($P < 0.001$) and female locations were characterized by greater ($P \leq 0.02$) grass height, shrub height, low cover, and total cover than random sites. Logistic regression indicated that microhabitat selection was similar between study areas; odds ratios indicated that odds of bobcat use increased by 0.998 (95% CI = 0.997–0.999) per 1 m increase in distance to drainage, 0.986 (95% CI = 0.978–0.993) per 1.0% increase in grass cover, by 1.024 (95% CI = 1.011–1.036) per 1 cm increase in grass height, by 1.013 (95% CI = 1.003–1.024) per 1% increase in forb cover, and by 1.028 (95% CI = 1.017–1.039) per 1% increase in medium cover. Our results were similar to other bobcat microhabitat selection studies, where bobcat relocations were associated with understory vegetation, drainages, and rugged terrain. These results identify the adaptability of the species to meet life history requirements in a variety of landscapes, and provide insight to how land use requirements vary within regional and management boundaries.

KEY WORDS Badlands, Black Hills, bobcat, *Lynx rufus*, microhabitat use, South Dakota

Bobcats (*Lynx rufus*) are a highly adaptable carnivore and are the most abundant North America wild felid (Cowan 1971, Anderson and Lovallo 2003). In spite of extensive land use changes since European colonization, bobcats occupy most of their original range (Hansen 2007). With the exception of Delaware, the species is distributed within the 48 contiguous states (Woolf and Hubert 1998), southern Canada and in northern and central Mexico (Anderson and Lovallo 2003). Relative to habitat selection, bobcats have been well studied at the level of the home range (second-order selection; Johnson 1980), but limited research has addressed the small scale variation of vegetative and structural components within areas used by bobcats.

In South Dakota, microhabitat selection by bobcats is poorly understood. Vegetative structure and environmental conditions are highly variable within a plant association or seral stage; therefore, quality of a vegetation type can vary greatly (North and Reynolds 1996). Furthermore, specific microhabitat features found within a home range are likely important for prey items, resting-loafing cover, and escape cover for bobcats. Therefore, we hypothesized that despite differences in forested and prairie ecoregions, bobcats would select for similar microhabitat features. We predicted that bobcats would select for rugged landscape closer to drainages containing greater amounts of understory vegetation. An understanding of the importance of these features may allow managers to predict the effects of human disturbance and habitat modification on future habitat-use patterns of bobcats (Kolowski and Woolf 2002).

STUDY AREA

Our study was conducted from July 2006 to June 2008 in two regions of southwestern South Dakota (Fig. 1). The first site consisted of 1,459 km^2 in Pennington, Jackson, and Meade counties, South Dakota (hereafter Badlands site). This site included the North Unit of Badlands National Park, Buffalo Gap National Grassland land holdings, private

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rangelands, and portions of the Cheyenne and White rivers. The second site consisted of 1,601 km^2 in the southern and central Black Hills, covering portions of Pennington, Custer, and Fall River counties, South Dakota (hereafter Black Hills site).

Badlands National Park is characterized by highly eroded badland formations, resulting in steep, broken terrain punctuated with narrow slot canyons and spires that attain elevations up to 992 m above mean sea level. Average summer (June–August) annual precipitation was 43.6 cm and temperature ranged from 19.0–22.8° C (South Dakota Office of Climatology 2011). Badlands formations were comprised primarily of bare soil with sparse woody vegetation such as rabbit brush (*Chrysothamnus nauseous*), prairie sagewort (*Artemesia frigida*), and Rocky Mountain juniper (*Juniperus scopulorum*) interspersed throughout the landscape. Areas with minimal slope within formations also contained grasses such as western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Nassella viridula*), blue grama (*Bouteloua gracilis*), and buffalograss (*Buchloe dactyloides*; Johnson and Larson 1999, Weedon 1999). Apart from badland formations, rolling hills of mixed-grass prairie characterized the area surrounding the park. Vegetation included cheat grass (*Bromus tectorum*), smooth brome (*B. inermis*), buffalograss, and western wheatgrass. Although prairie dominated the landscape, riparian forest zones were found along the White and Cheyenne rivers with woody vegetation consisting of plains cottonwood (*Populus deltoides* var. *occidentalis*), Rocky Mountain juniper, green ash (*Fraxinus pennsylvanica*), willow (*Salix* spp), and burr oak (*Quercus macrocarpa*; Johnson and Larson 1999). Less than 1% of the badlands area was used for row-crop agriculture, with pasture comprising the majority of the area (Smith et al. 2002).

The Black Hills is an isolated mountain area in western South Dakota and northeastern Wyoming. Elevation of the Black Hills ranges from 975–2,134 m above mean sea level (Sieg and Severson 1996). Forests of the region were comprised primarily of ponderosa pine (*Pinus ponderosa*) interspersed with small stands of quaking aspen (*P. tremuloides*) and paper birch (*Betula papyrifera*), which occur at higher elevations (McIntosh 1949, Orr 1959, Hoffman and Alexander 1987). Understory vegetation included snowberry (*Symphoricarpos albus*), serviceberry (*Amelanchier alnifolia*), Woods' rose (*Rosa woodsii*), and cherry species (*Prunus* spp.), with herbaceous vegetation comprised of western wheatgrass, sun sedge (*Carex inops*), little bluestem (*Schizachyrium scoparium*), and smooth brome (Larson and Johnson 1999). Average summer temperature of this region ranged from 15.4–18.9° C and annual precipitation was 51.3 cm (South Dakota Office of Climatology 2011). This area was a mixture of federal, private, and state lands including Wind Cave National Park, Custer State Park, Black Hills National Forest, private holdings, and State Game Production Areas.

METHODS

From July to October 2006, we captured bobcats using #3 padded foot-hold traps (Woodstream Corporation, Lititz, PA, USA) at the Badlands study site. From October 2007 to March 2008 we trapped bobcats using either padded #3 foot-hold traps or home constructed cage traps with guillotine style doors (109 cm × 38 cm × 53 cm; FSL Enterprises, Pringle, SD, USA) at the Black Hills study site. We used different combinations of commercially produced lures and baits procured from road killed white-tailed deer (*Odocoileus virginianus*), cottontail rabbits (*Sylvilagus floridanus*), black-tailed prairie dogs (*Cynomys ludovicianus*), and ring-necked pheasants (*Phasianus colchicus*). We selected trap locations based on tracks and feces (scat) left by bobcats, and checked traps daily at sunrise.

We immobilized captured bobcats using an intramuscular injection of 4 mg/kg ketamine and 0.08 mg/kg medetomadine and used 0.4 mg/kg atipamazole as an antagonist (Kreeger and Arnemo 2007). To prevent possible infection associated with capture we administered a subcutaneous injection of a broad-spectrum antibiotic (Combi-Pen 48, Bimeda, Irwindale, CA, USA) at an approximate rate of 1 ml per 7 kg of total weight. We weighed individuals to the nearest 0.1 kg using a digital hand-held scale (ES-55, Salter Brecknell, Fairmont, MN, USA), determined sex, aged individuals as either juveniles or adults using canine eruption and tooth wear (Johnston et al. 1987), and fitted captured bobcats with GPS collars (<350 g; GPS 3300, Lotek Wireless Inc., Newmarket, Ontario, Canada) with programmed release mechanisms. Collars were programmed to record one location every three hours for 1 year from date of capture. Accuracy of locations averaged ± 21.5 m in open fields and ± 23.5 m in mature coniferous forest (Mallett 2010). Animal handling methods used in this project followed guidelines approved by the American Society of Mammalogists (Sikes et al. 2011) and were approved by the Institutional Animal Care and Use Committee at South Dakota State University (Approval no. 09–013A).

We selected sets of locations randomly from all GPS locations of radio-collared bobcats at both the Badlands and Black Hills sites and compared them to randomly generated (pseudo-absence) points within bobcat home ranges to estimate habitat selection. We sampled bobcat use locations equally among radio-collared individuals at each study site (e.g., 6 males captured at Badlands study site, approximately 17 relocations per male). We randomly selected bobcat use locations from downloaded radio collar data and we separated use locations by ≥24 hrs to minimize autocorrelation. We generated random points within summer home range polygons of bobcats (Mosby 2011) using the random point generator tool in ArcGIS 9.2 (ESRI, Inc., Redlands, CA, USA).

During summer (Jun–Aug) 2007 and 2008, we measured 20 variables at bobcat locations and random points to quantify vegetative structure and identify landscape features that potentially influence bobcat habitat selection. We measured percent slope with a clinometer (SUUNTO, Vantaa, Finland) and estimated distance to badlands/rock formations (dbad), distance to prairie dog towns (dpd), and distance to drainage features (ddra) visually in the field using digital topographic maps obtained from the USDA Forest Service and National Park Service. We estimated number of trees and large shrubs (lgshrub) per ha by counting all tree species with >6 cm diameter at breast height (dbh) and shrubby vegetation greater than 1 m in height within a circular 0.041 ha plot with relocation or random point representing plot center. We measured tree diameter (trdia) to the nearest centimeter with a diameter tape (Forestry Suppliers, Jackson, MS, USA). We visually estimated percent cover of grass, forb, small shrubs (<1 m), and bare ground at 9, 1.0-m^2 quadrats spaced equally along two perpendicular transects originating at plot center. We estimated average height of grass (grassht), forb (forbht), and small shrub (shrubht) vegetation to the nearest 5-cm using a measuring stick. We estimated amount of low (lcov), medium (mcov), high (hcov) cover, and total visual cover (tcov) at 4 locations 10 m in cardinal directions from points (random and relocation) using a 2-m high cover pole (Griffith and Youtie 1988).

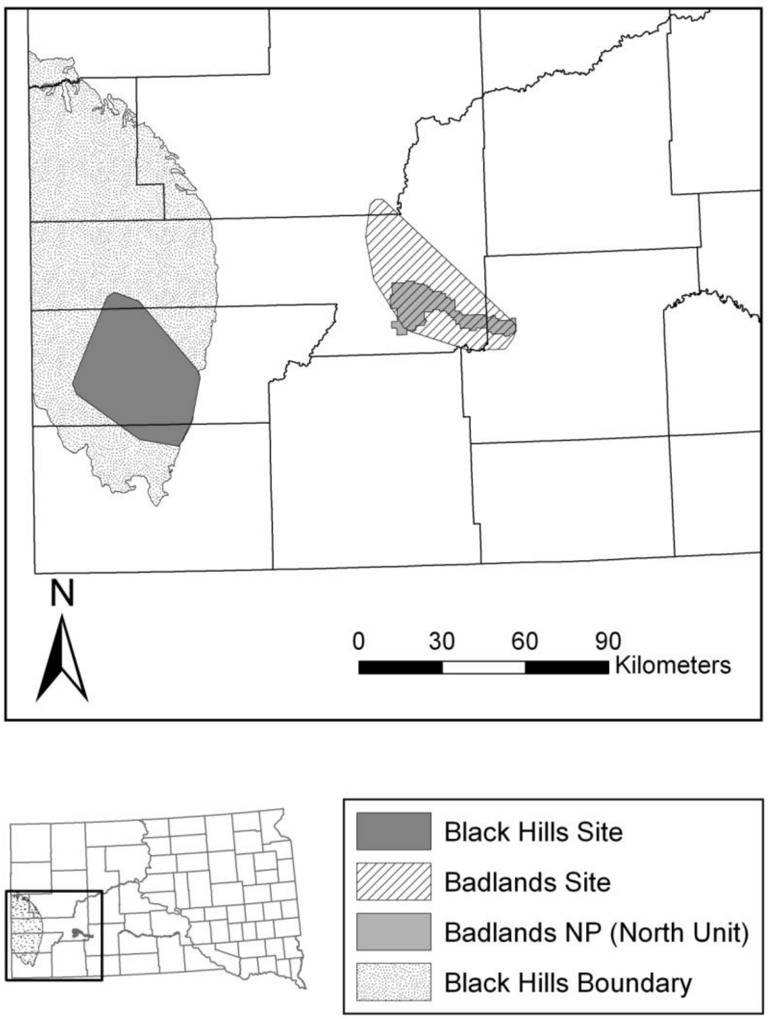

Figure 1. Location of Badlands and Black Hills study sites for evaluating microhabitat selection of bobcats (*Lynx rufus*) in western South Dakota, 2006–2008.

We used multivariate analysis of variance (MANOVA) to test for relationships between sex, study site, and bobcat use and random sites. We used logistic regression to determine relationships between microhabitat variables and bobcat selection. Prior to modeling, we tested for colinearity between predictor variables using variance inflation (Allison 1999) and posited 15 models of how bobcat habitat selection might be influenced by microhabitat variables in Badlands and Black Hills regions. We selected model parameters based on biological importance to bobcats (see Hall and Newsom 1976, Knowles 1985, Litvaitis et al. 1986, Anderson 1990, Kolowski and Woolf 2002). We used Akaike's Information Criterion (AIC) to select models that best described the data and considered models differing by ≤2 ΔAIC from the selected model as potential alternatives (Burnham and Anderson 2002). We used Akaike weights (w_i) as an indication of support for each model. Models ≤2 ΔAIC from the best model were examined to determine if they contained ≥1 parameter more than the best model but had essentially the same maximized log-likelihood as the best model. In these cases, models with additional parameters were considered unsupported and non-competitive (Burnham and Anderson 2002, Arnold 2010). Thus, we eliminated these models from consideration in our analyses. We used the Hosmer-Lemeshow goodness-of-fit test to determine model fit ($P > 0.05$ indicated appropriate model fit; Hosmer and Lemeshow 2000). We conducted statistical tests using SAS version 9.1 (SAS Institute 2000) with an experimental wide error rate of 0.05.

RESULTS

In 2006, we captured and radio collared 10 bobcats (4 female, 6 male) at the Badlands study site, and in 2007–2008, we captured and radio collared 10 bobcats (7 female, 3 male) at the Black Hills study site. We analyzed summer microhabitat characteristics at 176 bobcat locations (100 female, 76 male) and 148 random points at the Badlands site, and at 173 bobcat locations (111 female, 62 male) and 173 random points at the Black Hills site. Microhabitat characteristics at bobcat use sites differed ($F_{17, 305} = 19.77$, $P < 0.001$) among study sites (Table 1). Bobcats in the Badlands were located at increased distances to drainages and at sites with increased grass height compared to bobcat locations at the Black Hills site. Bobcat locations in the Black Hills had greater percent slope, number of trees, tree diameter, number of large shrubs, percent shrubs, shrub height, percent low cover, percent medium cover, percent high cover, and percent total cover than those at the Badlands site (Table 1).

Microhabitat characteristics varied between use and random sites at the Badlands ($F_{18, 304} = 3.59$, $P < 0.001$) and Black Hills ($F_{17, 276} = 5.31$, $P < 0.001$) sites (Table 1). At the Badlands study site, bobcats were associated with decreased distance to badlands formations and drainages, lower percent grass, increased tree diameter, and increased grass height, percent shrubs, shrub height, percent bare ground, percent low cover, percent medium cover, percent high cover, and percent total cover compared to random sites (Table 1). Additionally, number of large shrubs was slightly higher at bobcat use than random sites. In the Black Hills, bobcats were associated with decreased distance to drainages and percent grass, and increased percent slope, tree diameter, large shrubs, percent shrubs, shrub height, percent bare ground, percent low cover, percent medium cover, and percent total cover compared to random sites (Table 1). Additionally, percent forbs tended to be greater at bobcat use compared to random sites.

Microhabitat characteristics at use sites varied with sex of bobcat at Badlands ($F_{18, 157} = 2.85$, $P < 0.001$) and Black Hills ($F_{17, 128} = 5.82$, $P < 0.001$) study sites (Table 2). Female bobcats at the Badlands study site were associated with greater percent slope and increased distance to prairie dog towns and drainages than males, whereas male bobcats were associated with greater distance to Badlands, percent forb, and forb height than were females. At the Black Hills study site, female bobcats were associated with greater grass height, shrub height, percent low cover, and percent total cover than those of males, whereas male bobcats were more associated with greater elevation than were females.

The model {ddra + grass + grassht + forb + mcov} was the best approximating model ($w_i = 0.86$) for estimating bobcat microhabitat selection at both study sites (Table 3). This model was ≥4.65 ΔAIC from remaining models and weight of evidence supporting this model was ≥10.75 times greater than remaining models. Parameter estimates (Table 4) and logistic odds ratios indicated that the probability of bobcat selection increased by 0.998 (95% CI = 0.997–0.999) per 1 m increase in distance to drainage, 0.986 (95% CI = 0.978–0.993) per 1.0% increase in grass coverage, by 1.024 (95% CI = 1.011–1.036) per 1 cm increase in grass height, by 1.013 (95% CI = 1.003–1.024) per 1% increase in forbs coverage, and by 1.028 (95% CI = 1.017–1.039) per 1% increase in medium cover. Results of the Hosmer-Lemeshow goodness-of-fit test ($P = 0.785$) indicated predictive capability of the model was acceptable.

DISCUSSION

Microhabitat selection by bobcats has been documented in southern Illinois; bobcats were associated with 58% higher understory stem densities, were 66% closer to permanent water features, and used 32% thicker vegetative cover compared to random locations during summer (Kolowski and Woolf 2002). Winter locations of bobcats were associated with 127% higher understory stem densities and 5% higher log-wood ground cover, and were 66% closer to permanent water than were random locations (Kolowski and Woolf 2002). Bobcats likely were selecting for microhabitat features that enhanced concealment, provided resting habitat, were linked with optimal habitat for prey species, and were associated with water features (e.g., streams), which may act as travel corridors (Kolowski and Woolf 2002). In southeastern Colorado, an analysis of 11 habitat variables at diurnal resting-loafing areas used by bobcats identified selection for areas of steeper slopes, rocky areas with denser vertical cover, and little herbaceous cover; features that promote protection from extreme temperatures, concealment, and escape cover from predators

(Anderson 1990). In comparison, bobcats inhabiting the Badlands and Black Hills regions selected for topographic features associated with drainages and vegetative characteristics that provided cover.

Our hypothesis that despite differences in forested and prairie ecoregions, bobcats would select for similar microhabitat features was supported. Bobcats in both study areas selected for medium visual cover, which represented visual obscurity provided by both vegetative (shrubs and tall grasses) and structural (i.e., rock or badlands formation) features 50 to 100 cm above ground level. Selection for vertical vegetative/structural cover has been documented in other regions, and sites characterized with cover may serve as favorable sites for hunting, escape cover, and diurnal resting-loafing sites (Hall and Newsom 1976, Knowles 1985, Litvaitis et al. 1986, Anderson 1990, Kolowski and Woolf 2002).

Table 1. Mean and SE of microhabitat characteristics for bobcat use (n = 349) and random (n = 319) sites in the Badlands and the Black Hills of South Dakota, USA, during summer 2006–2008.

	Badlands				Black Hills			
	Use (n = 176)		Random (n = 147)		Use (n = 173)		Random (n = 172)	
Habitat[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Slope[c,d]	13.0	1.6	11.7	2.3	24.7	1.3	16.6	1.1
Dbad	121.8	16.4	164.3	14.5	NA	NA	NA	NA
Dpd	1,078.2	87.9	957.7	90.7	NA	NA	NA	NA
Ddra[b,c,d]	136.9	11.1	198.2	15.4	84.2	6.5	134.9	12.5
Trees[d]	0.7	0.4	0.1	0.1	8.2	1.0	6.3	0.9
Trdia[b,c,d]	1.3	0.4	0.3	0.2	16.8	1.6	11.2	1.0
Lgshrub[b,c,d]	1.8	0.6	0.5	0.3	32.1	5.0	17.4	2.7
Grass[b,c]	35.7	2.2	46.1	2.9	35.4	1.7	45.7	1.9
Grassht[b,d]	34.5	1.6	30.1	1.6	23.1	0.9	22.5	0.9
Forb	16.6	1.5	15.6	1.8	14.3	1.2	12.5	0.8
Forbht	22.2	1.3	20.9	1.2	20.8	1.3	20.9	1.1
Shrub[b,c,d]	4.4	0.6	2.3	0.3	7.0	0.8	4.8	0.7
Shrubht[b,c,d]	21.4	2.0	12.2	1.4	40.8	2.8	28.8	2.9
Bare[b,c]	42.4	1.5	34.0	2.9	43.3	2.1	36.4	2.1
Lcov[b,c,d]	34.0	1.1	28.3	1.1	37.7	1.0	31.0	1.1
Mcov[b,c,d]	19.8	1.3	10.2	1.2	27.5	1.4	16.7	1.3
Hcov[b,d]	24.6	2.2	12.8	2.0	44.7	2.7	33.0	5.4
Tcov[b,c,d]	87.3	4.1	59.8	3.8	117.9	4.5	81.3	4.7
Elev[c]	NA	NA	NA	NA	1,333.2	18.5	1,319.3	17.9

[a] Slope = % slope, Dbad = distance (m) to badland formation, Dpd = distance (m) to prairie dog (*Cynomys ludovicianus*) town, Ddra = distance (m) to drainage, Trees = trees/ha measured as trees with dbh >6.4 cm, Trdia = mean tree diameter of trees with dbh >6.4 cm, Lgshrub = number of large shrubs >1 m in height, Grass = % grass coverage, Grassht = mean grass height (cm), Forb = % forbs coverage, Forbht = mean forbs height, Shrub = % small shrub (<1 m in height) coverage, Shrubht = mean small shrub height (cm), Bare = % bare ground coverage, Lcov = % low cover (<0.5 m of cover pole obscured by visual cover; Kolowski and Woolf 2002), Mcov = % medium cover (0.5–1.0 m of cover pole obscured by visual cover; Kolowski and Woolf 2002), Hcov = % high cover (1.1–2.0 m of cover pole obscured by visual cover; Kolowski and Woolf 2002), Tcov = % total cover (0.0–2.0 m of cover pole obscured by visual cover; Kolowski and Woolf 2002); [b] Indicates differences between use and random microhabitat sites ($P < 0.05$) at Badlands study area; [c] Indicates differences between use and random microhabitat sites ($P < 0.05$) at Black Hills study area; [d] Indicates differences in bobcat use among study sites.

Table 2. Mean and SE of microhabitat characteristics for male and female bobcat sites (n = 349) in the Badlands and the Black Hills in South Dakota, USA, during summer 2006–2008.

	Badlands				Black Hills			
	Male (n = 76)		Female (n = 100)		Male (n = 62)		Female (n = 111)	
Habitat[a]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Slope[b]	8.0	1.9	16.8	2.3	27.0	2.5	23.5	1.6
Dbad[b]	190.6	30.0	69.5	16.0	NA	NA	NA	NA
Dpd[b]	668.2	102.7	1,389.7	125.2	NA	NA	NA	NA
Ddra[b]	97.4	15.5	167.1	14.9	89.0	12.3	81.5	7.5
Trees	1.4	0.9	0.3	0.1	5.1	1.0	9.9	1.4
Trdia	1.8	0.7	1.0	0.4	13.0	1.7	18.9	2.2
Lgshrub	3.0	1.3	0.9	0.5	19.9	4.8	38.7	7.2
Grass	35.6	3.3	35.8	3.0	36.2	3.0	35.0	2.0
Grassht[c]	35.3	2.6	33.9	2.0	18.9	1.3	25.5	1.2
Forb[b]	21.2	2.8	13.1	1.4	16.6	2.2	13.1	1.3
Forbht[b]	25.1	2.2	20.0	1.6	20.1	2.5	21.2	1.5
Shrub	5.1	1.1	4.1	0.7	6.1	1.4	7.5	1.0
Shrubht[c]	23.5	3.3	19.9	2.4	33.5	4.8	44.8	3.4
Bare	38.9	3.7	45.1	3.4	41.3	3.2	44.5	2.7
Lcov[c]	0.7	0.0	0.7	0.0	33.3	2.1	40.1	1.1
Mcov	0.4	0.0	0.4	0.0	24.4	2.6	29.2	1.6
Hcov	0.2	0.0	0.3	0.0	35.9	4.8	49.5	3.1
Tcov[c]	0.4	0.0	0.4	0.0	104. 6	8.6	125.2	5.1
Elev[c]	NA	NA	NA	NA	1,437.3	33.6	1,258.5	16.4

[a] Slope = % slope, Dbad = distance (m) to badland formation, Dpd = distance (m) to prairie dog (*Cynomys ludovicianus*) town, Ddra = distance (m) to drainage, Trees = trees/ha measured as trees with dbh >6.4 cm, Trdia = mean tree diameter of trees with dbh >6.4 cm, Lgshrub = number of large shrubs >1 m in height, Grass = % grass coverage, Grassht = mean grass height (cm), Forb = % forbs coverage, Forbht = mean forbs height, Shrub = % small shrub (<1 m in height) coverage, Shrubht = mean small shrub height (cm), Bare = % bare ground coverage, Lcov = % low cover (<0.5 m of cover pole obscured by visual cover; Kolowski and Woolf 2002), Mcov = % medium cover (0.5–1.0 m of cover pole obscured by visual cover; Kolowski and Woolf 2002), Hcov = % high cover (1.1–2.0 m of cover pole obscured by visual cover; Kolowski and Woolf 2002), Tcov = % total cover (0.0–2.0 m of cover pole obscured by visual cover; Kolowski and Woolf 2002); [b] Indicates differences between male and female microhabitat selection ($P < 0.05$) at Badlands study area; [c] Indicates differences between male and female microhabitat selection ($P < 0.05$) at Black Hills study area.

Average length from pad of foot to the spine was 42 cm among collared bobcats, placing eye level in the lower bounds of the measure of medium visual cover. Bobcats are characterized as a spot and stalk or sit and wait predator (Husseman et al. 2003); thus, vegetation and or structural features representing visual obscurity are likely important for both prey items, and successful procurement of prey (Palomares 2001, Tews et al. 2004). For bobcats, vegetative and structural features in this spatial extent may represent a preferred height for cover used in hunting, resting-loafing areas, and escape cover, and this component of habitat selection was similarly selected by bobcats despite differences in vegetative communities and structural features of our two study areas.

In both study sites, the probability of use by bobcats decreased with increased distance from a drainage feature.

In agricultural areas of the Mississippi floodplain, riparian zones often provided the only vegetative cover and high stem density in the area, and bobcats were often located along these zones (Kolowski and Woolf 2002). In the forested regions of southern Illinois, Kennedy (1999) found that bobcats regularly traveled along stream bottoms or their associated ridge tops. In our study areas, drainages were associated with increased understory vegetation, which was represented by increased shrub height at bobcat locations in the Badlands, and increased shrub cover at bobcat locations in the Black Hills. In the Badlands, drainages provided structural cover for travel and concealment, and with possible protection from fires and increased soil moisture, woody vegetation was found in greater abundance near drainages in this open prairie landscape. While the Black Hills is a forested region, forest management practices were focused on shelter wood techniques that created even aged, relatively uniform stands of ponderosa pine (Uresk et al. 2000). Time from timber harvest to canopy closure differs by method of harvest and site characteristics but after the onset of canopy closure, understory plant biomass and species diversity decrease (Wrage 1994, Uresk et al. 2000). After canopy closure, these stands are largely absent of understory shrub species such as bearberry (*Arctostaphylos uva-ursi*), snowberry, and juniper (*Juniperus* spp.; DePerno et al. 2002). Due to this absence of understory shrub vegetation, these forest stands may not provide suitable vegetation for prey species or stalking cover for bobcats. Thus, forest management practices in the Black Hills may limit potential for features important to bobcats and in turn restrict use of the landscape to areas not under strict management for timber production.

Table 3. A priori logistic regression models to determine bobcat summer microhabitat selection in the Badlands and the Black Hills of South Dakota, during summer 2008–2009.

Model[a]	K[b]	−2LL	AIC[c]	ΔAIC[d]	w_i[e]
ddra + grass + grassht + forb + mcov	6	822.62	834.62	0.00	0.86
ddra + treedia + grass + grassht + forb + mcov	7	825.27	839.27	4.65	0.08
Ddra*site + treedia + grassht + grass + mcov*site	9	823.47	841.47	6.84	0.03
ddra + grass + grassht + mcov	5	833.32	843.32	8.69	0.01
ddra + treedia + grassht + grass + mcov	6	831.99	843.99	9.37	0.01
ddra|site + grass + grassht + mcov*site	8	828.98	844.98	10.35	0.00
ddra*site + slope*site + shrub*site + mcov*site	10	825.47	845.47	10.84	0.00
slope + ddra + treedia + grass + grassht + mcov	7	831.98	845.98	11.35	0.00
ddra + grass + grassht + forb + lcov	6	836.31	848.31	13.68	0.00
slope*site + shrub*site + lcov*site + mcov*site + ddra*site	12	825.02	849.02	14.39	0.00
ddra*site + grassht mcov*site	7	843.41	857.41	22.78	0.00
ddra + shrubht + grassht + mcov	5	851.09	861.09	26.47	0.00
slope + ddra + grassht + shrubht + mcov	6	850.24	862.24	27.62	0.00
ddra + mcov	3	857.17	863.17	28.55	0.00
ddra*site + lcov*site	6	870.74	882.74	48.11	0.00

[a] Slope = % slope, Ddra = distance (m) to drainage, Trdia = mean tree diameter of trees with dbh >6.4 cm, Grass = % grass coverage, Grassht = mean grass height (cm), Forb = % forbs coverage, Shrub = % small shrub (<1 m in height) coverage, Shrubht = mean small shrub height (cm), Lcov = % low cover (<0.5 m of cover pole obscured by visual cover; Kolowski and Woolf 2002), Mcov = % medium cover (0.5–1.0 m of cover pole obscured by visual cover; Kolowski and Woolf 2002), *site = indicated an interaction between habitat variable and study site; [b] Number of parameters; [c] Akaike's Information Criterion (Burnham and Anderson 2002), [d] Difference in AIC relative to minimum AIC; [e] Akaike weight (Burnham and Anderson 2002).

Sex-specific habitat selection is well documented in bobcat populations and has been attributed to differences in life history characteristics (Anderson 1987, Litvaitis et al. 1987, Lovallo and Anderson 1996). Previous work has suggested that use of a landscape by female bobcats was more influenced by prey abundance and energetic demands, while male use was influenced by maximizing breeding opportunities (Bailey 1972, Anderson 1987). This strategy has been documented with other solitary carnivores (Sandall 1989, Thompson and Jenks 2010). Females at the Badlands site selected for areas with slopes twice as steep as those used by males and also were closer to badlands formations compared to males. The erosive processes that shaped the Badlands also formed caves, alcoves, and ledges that provide suitable sites for denning and escape cover for females and their young. Anderson (1987) observed that juvenile and female bobcats were rarely found >100 m from cover in southeastern Colorado. This close association between female bobcats and cover was potentially due to high predation (n = 4 bobcats; 3 juvenile, 1 adult female) by coyotes (*Canis latrans*). In the Black Hills, percent grass and shrub cover varied between use and random points but not between sexes. Instead, female locations were associated with taller grass and shrubs. Moreover, female locations were associated with greater values for the variables low and total visual cover. These variables have been associated with features important to bobcat survival (Rolley and Warde 1985; Kolowski and Woolf 2002). With the costs associated with rearing young, female bobcats likely select for small scale features in the landscape that provided high prey density and vegetative/structural characteristics for suitable denning sites. In the Badlands, formations likely play this functional role whereas in the Black Hills, a combination of increased understory vegetation in the form of shrubs and tall grass, and physical characteristics in the form of steep slopes and drainage features could provide components necessary for the rearing of young.

Male bobcats were located closer to drainage features than random locations in the Badlands. Use of these drainages may have been related to their suitability as travel corridors in the open prairie landscape. Male bobcats have been known to use creek bottoms and their corresponding ridge tops as travel corridors (Shiflet 1984). At the Badlands site, male bobcats may have used small drainages found in the prairie landscape to access quality habitat inhabited by female bobcats. Male use of prairie dog towns, as observed during our study, also has been documented in Montana; Knowles (1985) observed that 33% of male bobcat relocations were in prairie dog towns whereas only 6% of female relocations were in these areas. Although a possible food source, prairie dogs require hunting in open, sparsely vegetated areas. Increased exposure to predation may outweigh potential benefits for female bobcats and their young, but not for larger male bobcats.

In South Dakota, analysis of food remains in 164 bobcat stomachs identified that rabbits (*Sylvilagus* spp. and *Lepus* spp.), voles and mice (*Microtus* spp. and *Peromyscus* spp.), and deer (*Odocoileus* spp.) occurred in 56, 32, and 7% of stomachs, respectively (Nomsen 1982). Above ground bedding sites used by eastern cottontails (*S. floridanus*) have been characterized by dense, woody vegetation within 0.5 m of ground level (Althoff et al. 1997). Desert cottontail (*S. audubonii*) selection has been characterized by stream bottoms with abundant willows (*Salix* spp.; Orr 1940), whereas Nuttall's cottontails (*S. nuttallii*) have been known to occupy rocky ravines and sagebrush-covered hills (Dice 1926). As with other lagomorphs, white-tailed jackrabbits (*L. townsendii*) are known to feed in open areas but in close proximity to dense cover, which is utilized as escape terrain in addition to resting sites during inactive periods of the day (Fautin 1946). Three species of voles (*Microtus* spp.) native to South Dakota had niche preferences for rock, grass-dominated areas, wet and dry grasslands, grass-dominated fields, and marsh and bog mats, respectively (Martin 1956, Getz 1961, Pugh et al. 2003). Selection by bobcats for small scale vegetative and structural microhabitats likely enhances their ability to procure these potential food items.

Table 4. Parameter estimates, standard errors, and significance tests from the top-ranked logistic regression model to determine microhabitat selection of bobcats in the Badlands and the Black Hills of South Dakota, USA, 2006–2008.

Parameter[a]	β	SE	Wald chi-square	*P*-value
Intercept	−0.366	0.257	2.17	0.16
Ddra	−0.002	<0.001	14.14	<0.001
Grass	−0.014	0.004	15.26	<0.001
Grassht	0.023	0.006	14.38	<0.001
Forb	0.013	0.005	6.45	0.01
Mcov	0.027	0.005	26.26	<0.001

[a] Ddra = distance (m) to drainage, Grass = % grass coverage, Grassht = mean grass height (cm), Forb = % forbs coverage, Mcov = % medium cover (0.5–1.0 m of cover pole obscured by visual cover; Kolowski and Woolf 2002).

MANAGEMENT IMPLICATIONS

In South Dakota, bobcats were able to meet life history requirements in both forested and prairie landscapes, and different vegetative and structural features provided similar functions in bobcat habitat selection. To enhance habitat for bobcat populations in the Black Hills, land managers could promote practices to increase understory vegetation in the form of woody shrubs and early successional forest through a combination of prescribed burning and forest stand thinning, and protection of riparian zones to ensure persistence of understory vegetation important for prey species. In the western prairie regions of the state, drainage areas likely are vital in providing the increased vegetative cover for successful hunting of prey items, and as travel corridors that connect areas with suitable habitat for bobcats. Our findings will help managers to assess the effects of human disturbance, including habitat modifications, on bobcats occupying what might be considered non-typical terrain for the species.

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