Wolf, *Canis lupus*, Den Site Selection in the Rocky Mountains

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Because mortality of Wolves, *Canis lupus*, is highest during the first six months of life, den site selection may affect reproductive success of Wolf populations. We studied fine-scale denning habitat selection (within 100 m of den site) by comparing field-measured characteristics of 22 dens in Idaho, Montana, and Alberta with 22 paired random contrast locations within pack home ranges. In order of importance, Wolves denned in areas with greater canopy cover, hiding cover, herbaceous ground cover, and woody debris, and were closer to water than paired random sites. Thus Wolves may select den sites for physical protection and available water. We also studied coarse-scale denning habitat selection by comparing 35 Wolf dens with 35 paired contrast locations in Idaho, Montana, and Wyoming with respect to six remotely-sensed variables (elevation, slope, coniferous forest cover, solar radiation, distance to water, and distance to roads). Although these variables did not differ (univariate $P > 0.10$) between den and contrast locations, a Mahalanobis-distance model using four remotely-sensed variables (slope, elevation, coniferous forest cover, and solar radiation) suggested > 85% of dens would occur in potential denning habitat occupying < 12% of the Wolf recovery areas in the northern Rocky Mountains. This model may be useful for identifying likely den locations in areas not yet occupied by Wolves. Wolf core use areas, including den areas, showed higher intensity of use throughout the year when compared to the entire territory.

Key Words: Wolf, *Canis lupus*, den, modeling, reproduction, selection, Montana, Idaho, Wyoming, Alberta.

Numerous studies have focused on Wolf, *Canus lupus*, reproduction and denning (e.g., Mech 1970; Ballard and Dau 1983; Fuller 1989; Ciucci and Mech 1992; Matteson 1992; Unger 1999), but den site selection in forested ecosystems is not completely understood (Norris et al. 2002). Because most pup mortality occurs within the first six months, site selection and activity around the den can affect reproductive success of the pack (Harrington and Mech 1982).

Wolf population numbers and distribution have increased in the Northern Rocky Mountains since reintroductions in central Idaho and Yellowstone National Park in 1995 and 1996 (U.S. Fish and Wildlife Service et al. 2006). Den site selection by recolonizing Wolves may reflect selection for habitat characteristics relatively unconstrained by tradition, territorial interactions, or other social factors. Habitat models using data collected on a recolonizing population can be used to suggest important factors in den site selection.

Wolf territories in the Northern Rocky Mountains average over 500 km^2 (U.S. Fish and Wildlife Service et al. 2006), with activities concentrated in the den area during April-June. There are no previous reports assessing the importance of denning areas during the other 9 months of the year. If den areas are important year-round, den locations may be useful for prioritizing areas for management attention.

Our effort is the first to address Wolf den site selection in the northern Rocky Mountains since the reintroductions and is based on a larger number of dens than previous published studies of Wolf den site selection in North America (Ballard and Dau 1983; Ciucci and Mech 1992; Matteson 1992; Unger 1999; Norris et al. 2002). Our objectives were to (1) describe characteristics of den sites used by Wolves; (2) investigate factors influencing den site selection; (3) develop a predictive model of suitable den site habitat throughout the northern Rocky Mountains based on remotely-sensed data; and (4) examine location of den sites relative to home range boundaries.

Methods

Study area

This study was focused in the three United States northern Rocky Mountains Wolf recovery areas: Northwestern Montana, central Idaho, and Greater Yellowstone Area. The northern Rocky Mountains extend from northwestern Wyoming to the northern borders of western Montana and Idaho. This mountain range is bounded by the Great Plains to the east and the Columbia Plateau and Great Basin to the west. Volcanic activity has been the major factor forming these mountains (Kershaw et al. 1998). Receding glaciers have smoothed plains, cut broad valleys, and formed dramatic peaks. Some of the highest peaks include Gannett Peak in Wyoming (4 207 m), Granite Peak in Montana (3 904 m), and Borah Peak in Idaho (3 861 m). Because of the dramatic change in elevations and latitude, climate varies widely across the study area. Each of the three recovery areas exceeds 50 000 km^2 and is composed primarily of public lands. Primary ungulate prey of Wolves in this region include Elk (*Cervus elaphus*), White-tailed Deer (*Odocoileus virginianus*), Mule Deer (*O. hemionus*), and Moose (*Alces alces*).

Den site characteristics

Known and probable den site locations were provided by the Nez Perce Tribe in Idaho, the U.S. Fish and Wildlife Service in Montana, and Banff National Park in Alberta, Canada. Dens were found by evaluating aerial telemetry locations of collared wolves during the denning season (April-June). Probable den sites were integrated into the study only after ground crews were able to locate the dens and confirm recent Wolf use. We focused on investigating dens used since 2000. To reduce impact to Wolves, data were collected after aerial and ground telemetry of collared Wolves confirmed the pack was no longer using the den area. Because Wolves often use the same den in subsequent years (Ballard and Dau 1983; Mech and Packard 1990), we took precautions not to modify the den. We collected data at 22 dens (12 in Idaho, 8 in Montana, and 2 in Banff National Park, Canada), excluding dens that were last used before 2000, or dens where habitat modifications had occurred after the den was used by Wolves.

During June-October 2003, we measured 14 vegetative and topographic variables at den and contrast locations (Table 1). Data were collected at den *sites* (a 20 × 20 m plot centered on the den opening) and at den *areas* (the average of variables measured at 5 plots: one at the den opening and one each 50 m from the den opening in the cardinal directions). Hiding cover was recorded as the average percentage obscured of a 2 m cover pole observed from 15 m away in each cardinal direction (Griffith and Youtie 1988). Canopy density was estimated using a spherical densitometer (Lemon 1957).

Fine-scale habitat selection using field-collected data

For each den, we measured the same variables at a random contrast location within the home range of the pack. Home range boundaries were provided by the Idaho and Montana Wolf projects and Banff National Park and consisted of Minimum Convex Polygons based on radio-telemetry data. In some cases, where pack territories appeared stable from year to year and annual numbers of aerial radio locations were low, pack boundaries were based on radio locations pooled over several years (Ballard et al. 1987). For three packs for which home range data were not available, we chose a contrast site 1 km from the den in a random direction.

We compared den and contrast sites and areas using Wilcoxon's signed-ranks test (Zar 1999) for the 13 continuous variables and using Chi-square for presence of water within 100 m (the only categorical variable). Variables significantly different ($P < 0.10$) between den and contrast sites, and den and contrast areas were evaluated for multicollinearity. If Pearson Correlation (Zar 1999) coefficients indicated correlation ($|r| > 0.50$), variables with higher *P*-values were removed from the list of candidate variables. We created forward entry logistic regression models at the site (1-plot) and area (5-plot) scales. The criterion to enter and retain variables in the logistic regression model was $P < 0.20$ (Hosmer and Lemeshow 2000), using *P*-values associated with each variable's R statistic.

Coarse-scale habitat selection using remotely-sensed data and developing a predictive model of suitable den site habitat

Remotely-sensed data were available for the 20 dens in the United States at which we collected field data and an additional 15 den locations in Yellowstone National Park (YNP), for a total of 35 dens in the three northern Rocky Mountains recovery areas. We selected six variables that previous literature suggested were important in habitat selection by Wolves (Matteson 1992; Mladenoff et al. 1995; Oakleaf 2002) and that could be generated in ArcView from existing data layers (Table 2).

Direct solar radiation was estimated with SOLARFLUX (Rich et al. 1995; running under ARC/INFO with Digital Elevation Models). SOLARFLUX models incoming solar radiation based on slope, aspect, solar azimuth and zenith, time of year, topographic features, elevation, and atmospheric conditions. We used 15 April in this model as an average date for parturition in the northern Rocky Mountains (C. Mack, personal communication). Because Wolf home ranges and dens in the northern Rocky Mountains have been found primarily in coniferous forests (Matteson 1992; Oakleaf 2002), a coniferous forest GIS layer was derived from National Land Cover Data. This data layer was developed from 30 m resolution as a percentage of forested cells within 100 m of den and contrast site. Elevation and slope were derived from National Elevation Data (NED). Road and water data were derived from U.S. Geological Survey (2002) Digital Line Graphs (DLG) and Topologically Integrated Geographic Encoding and Referencing system [TIGER] (U.S. Census Bureau 2002). Distances from dens to water and roads were calculated with distance functions in ArcView. We did not distinguish among four TIGER road classes (primary highways with limited access; primary roads without limited access; secondary and connecting roads; and local, neighborhood, and rural roads).

We used Mahalanobis Distance (Krzanowski 1988; Podruzny et al. 2002; Farber and Kadmon 2003) to

TABLE 1. Descriptions, units, and sampling methods for habitat variables measured in the field at Wolf dens and paired random locations in the northern Rocky Mountains, USA and Alberta, Canada, 2003. Field-measured habitat characteristics (SE) associated with Wolf dens (n = 22) vs. contrasts (n = 22) for Wolf den site analysis. The *site* is a single 20×20m plot, and the *area* is the average of 5 such plots—the center plot plus plots located 50 m away in the cardinal directions). Variables differing significantly (α = 0.1, Wilcoxon's signed ranks test; bold font) were considered for entrance into the logistic regression model.

			Site			Area		
Variable	Units	Description and methods	Den	Contrast	*P*	Den	Contrast	*P*
Elevation	m	Measured with GPS unit.	1672 (397)	1756 (323)	0.25	1672 (397)	1756 (323)	0.25
Slope of site	degrees	Determined using a clinometer. Averaged slope along the fall line 10 m upslope and downslope.	15 (9)	13 (8)	0.27	15 (9.5)	14.5 (9)	0.69
Index of tree diameter	inches	Measured diameter of each tree >2" DBH touching the transect[a] tape.	7.4 (8.5)	5.8 (4.2)	0.17	5.8 (6.4)	7.1 (6.1)	0.16
Canopy closure	%	Estimated at plot center using a spherical densiometer (Lemon 1957).	88 (22)	59 (36)	**0.009**	65 (34)	60 (36)	0.19
Hiding cover	%	Average percent obscured of a 2-m high cover pole observed 15 m away in each cardinal direction (Griffith and Youtie 1988).	72 (24)	47 (30)	**0.007**	57 (23)	49 (29)	**0.026**
Presence of water within 100 m	categorical (0/1)	Presence or absence of standing water, permanent or ephemeral streams of any size within 100 m of den.	15	7	**0.017**	15	7	**0.017**
Herbaceous ground cover	%	Fraction of meter marks (n=63) on the transect[b] that lay above an herbaceous plant.	40 (15)	30 (17)	**0.020**	42 (18)	31 (18)	**<0.0005**
Leaf/needle litter	%	Fraction of meter marks (n=63) on the transect[b] that lay above leaf/needle litter.	28 (13)	29 (18)	0.88	26 (15)	30 (19)	**0.096**
Shrub cover	%	Fraction of meter marks (n=63) on the transect[b] that lay above a plant 20-200 cm tall.	12 (8)	18 (16)	0.14	15 (12)	16 (16)	0.80
Small woody debris	%	Fraction of meter marks (n=63) on the transect[b] that lay above woody debris 5-15 cm in diameter.	5 (4)	2 (2)	**0.046**	4 (4)	3 (4)	0.56
Large woody debris	%	Fraction of meter marks (n=63) on the transect[b] that lay above Woody debris >15 cm in diameter.	4 (6)	4 (6)	0.61	3 (4)	3 (4)	0.47
Soil cover	%	Fraction of meter marks (n=63) on the transect[b] that lay above bare soil, including rocky <2.5 cm in diameter.	6 (4)	8 (10)	0.98	5 (6)	7 (10)	**0.025**
Rock cover	%	Fraction of meter marks (n=63) on the transect[b] that lay above rocky material >2.5 cm in diameter.	1 (2)	5 (15)	**0.066**	2 (7)	5 (16)	**0.038**
Tree cover	%	Fraction of meter marks (n=63) on the transect[b] that touched a tree >200 cm tall or the tree root system.	5 (5)	5 (6)	0.36	4 (5)	5 (7)	0.82

[a] χ^2 test
[b] Three 20-m transects were placed 10m apart, perpendicular to the aspect of the hill.

TABLE 2. GIS variables used in habitat selection for Wolf den site analysis in the Northern Rocky Mountains, USA, 2003. Mean (SE) of remotely-sensed variables measured at Wolf dens (n = 35) and contrast sites (n = 35).

Variable	Units	Resolution	Source	Dens		Contrasts		P
Distance to Roads	m	1:100 000	USGS DLG (1983) [a,c] TIGER [b]	2654	(3432)	3039	(4855)	0.86
Distance to Water	m	1:100 000	USGS DLG (1983) [a,b] TIGER [c]	412	(311)	533	(483)	0.41
Coniferous Forest	0/1	30 m	GAP (USGS 2002)	59	(44)	54	(44)	0.48
Elevation	m	30 m	USGS NED	1916	(404)	2011	(389)	0.1
Slope	°	30 m	USGS NED	19	(16)	20	(16)	0.54
Solar Radiation	W/m^2	30 m	Based on NED, Calculated with SolarFlux [d]	5822696	(1351423)	5642444	(1500068)	0.54

[a] Idaho
[b] Montana
[c] Yellowstone National Park
[d] 15April, 0900-1500

USGS: United States Geological Survey
DLG: Digital Line Graphs
NED: National Elevation Data

model potential denning habitat across the study area. This measure of dissimilarity is the squared distance between the vector of habitat variables measured at any location in the landscape, and the mean vector for all den sites (n = 35). We used elevation, slope, solar radiation, and coniferous forest cover at 30 meter resolution as variables based on previous studies that suggested their importance (Mech 1970; Matteson 1992; Unger 1999). Distance to roads and water were not used because resolution of the data set was too coarse. Mahalanobis distances were calculated using an ArcView extension (Jenness 2003*).

Because Mahalanobis distances have no upper limit, the values were converted to Chi-square P-values (Clark et al. 1993). P-values closer to 0 reflect a high Mahalanobis distance and high dissimilarity to observed den habitat, where P-values closer to 1 are similar to den sites. Each P-value defines a habitat model. We evaluated models by calculating the percentage of Wolf dens and percentage of the landscape that exceeded various threshold P-values. We considered a model useful if it encompassed >85% of dens within suitable habitat that comprised < 25% of the landscape.

Location of dens within home range boundaries

To assess if Wolves located den sites within core use areas, we examined the location of each den relative to the home range boundaries. Fixed kernel home range estimators (Powell et al. 1997; Seaman et al. 1999) were generated using radio telemetry data, ArcView 3.2 (Environmental Systems Research Institute 1992) and the ArcView Animal Movement Extension (Hooge et al. 1999). We constructed 95% polygons to represent Wolf home ranges exclusive of outliers and 50% polygons to represent a core use area within home ranges. We used telemetry locations taken from 1 August of the previous year to 31 July of the denning year to calculate home ranges for this analysis. Although Seaman et al. (1999) suggested a minimum of 30 telemetry locations to generate a fixed kernel home range, three packs with 20-28 locations were included. Because telemetry flights are usually increased during the denning season (April-June), to determine den locations, a sampling bias existed. To reduce this bias, if >25% (¼ of the year) of locations for a home range were obtained during the denning period, we randomly removed locations from the denning period until that period included only 25% of all annual locations. Because not all packs were collared and some collared packs were not monitored for several months during the year, only eight Idaho dens and four Montana dens could be evaluated.

Results

Den site characteristics

Twenty-three of 25 dens were hillside excavations with an average slope of 15 ± 9 degrees (Table 1). Twelve of the hillside excavations were categorized as "open," since they were not directly under a tree; ten were under trees, and one was under a downed tree. Most dens were clean and dry with hair in the soil and hanging from the roof. Average height and width of entrances were 43.9 ± 18 cm and 48.3 ± 15 cm, respectively. Average depth of the excavations was 282 ± 139.9 cm. Most den holes descended with 17-42 degree slope for approximately one meter before leveling or slightly climbing to an enlarged birthing/nursing chamber. Interior measurements averaged 50.5 ± 25.9 cm for height and 90.3 ± 38.3 cm for width. Land ownership was: U.S. Forest Service (68%), National Park Service (12%), Bureau of Land Management (8%), private (8%) and state (4%).

The most common tree species at den sites was Douglas-fir (*Pseudotsuga menziesii*), followed in order of occurrence by Engelmann Spruce (*Picea engelmannii*), Lodgepole Pine (*Pinus contorta*), Trembling Aspen (*Populus tremuloides*), Grand Fir (*Abies grandes*), Western Larch (*Larix occidentalis*), and Limber Pine (*Pinus flexilis*). Major shrub species occurring at den sites, from most to least common included: snowberry (*Symphoricarpos albus* and *S. oreophilus*), rose (*Rosa* sp.), Grouseberry (*Vaccinium scoparium*), Creeping Oregon-grape (*Berberis repens*), Mountain Huckleberry (*Vaccinium globulare*), Saskatoon (*Amelanchier alnifolia*), Common Juniper (*Juniperus communis*),

TABLE 3. Logistic regression model predicting Wolf den sites (20×20m plot centered on den) vs. contrast sites in the Northern Rocky Mountains, USA, 2003.

Variable	Coefficient	SE	Coefficient/SE	*P*-value	R
Water within 100m	1.39	0.85	1.64	0.099	0.11
Canopy Cover	0.042	0.018	2.33	0.018	0.24
Herbaceous Cover	0.078	0.035	2.23	0.024	0.23
Small Woody Debris	0.21	0.13	1.62	0.11	0.094
Constant	-7.12	2.34	-3.04	0.002	

TABLE 4. Logistic regression model predicting Wolf den areas (the den site plus 4 similar satellite plots 50m from den) vs. contrast areas in the Northern Rocky Mountains, USA, 2003.

Variable	Coefficient	SE	Coefficient/SE	*P*-value	R
Hiding Cover	0.014	0.007	2.03	0.049	0.08
Herbaceous Cover	0.04	0.01	4.17	<0.005	0.22
Leaf/needle Cover	0.025	0.011	2.23	0.0666	0.23
Water within 100 m	1.31	0.33	3.97	0.0001	0.21
Constant	-2.73	0.6	-4.55	0	

Birch-leaved Spiraea (*Spiraea betulifolia*) and Big Sagebrush (*Artemisia tridentata*).

Compared to contrast sites, den sites had greater canopy closure, hiding cover, herbaceous ground cover, woody debris, but less rock (Table 1). Average canopy closure was 88 ± 22%. Average hiding cover was 82 ± 21% from 0-1 m above ground level, and 61 ± 26% from 1-2 m above ground level for a combined total of 72 ± 24%. Den areas had greater hiding cover, more herbaceous ground cover, but less leaf and pine litter than contrast areas (Table 1).

Fine-scale habitat selection using field-collected data

Six of the 14 habitat variables differed ($P < 0.10$) between den and contrast sites (single 20 × 20 m plots), and were candidates for the logistic regression model (Table 1). Canopy Cover and Hiding Cover were highly correlated ($|r| = 0.53$), so Hiding Cover was removed because it was less significant. The model (Table 3) included Water within 100 m, Canopy Cover, Herbaceous Cover, and Small Woody Debris; and classified 86% (19 of 22) of the contrast sites and 82% (18 of 22) of the den sites for a combined accuracy of 84%.

Six variables differed between den and contrast areas (clusters of five plots): Water within 100 m, Hiding Cover, Herbaceous Cover, Leaf/needle Cover, Soil Cover and Rock Cover, none of which exhibited multicollinearity. The model (Table 4) included Hiding Cover, Herbaceous Cover, Leaf/needle Cover, and Water within 100 m and classified 74% (16 of 22) of the contrast areas and 70% (15 of 22) of the den areas for a combined accuracy of 71%.

Coarse-scale habitat selection using remotely-sensed data and developing a predictive model of suitable den site habitat

None of the six variables derived from remotely-sensed data differed significantly between den and contrast sites (Table 2). Habitat characteristics varied considerably among Wolf dens such that 70% of the 35 dens were dissimilar (Mahalanobis $P \leq 0.40$ – Figure 1) to the mean habitat vector. But most of the Northern Rocky Mountains landscape was even more dissimilar to the mean habitat vector, with >80% of the study area having Mahalanobis $P < 0.10$. The 12% of the landscape that most resembled mean den habitat encompassed 89% of sampled Wolf dens, and the 18% of the landscape most similar to the mean encompassed 91% of the dens (Figure 1).

Location of dens within home range boundaries

Eleven of 12 dens were located in the 50% core use area. The kernel estimator identified two or three discontinuous core areas for five territories. In these cases, three of five dens were located in the largest of the 50% core areas. The 50% kernel size ($\bar{x}$ = 148 ± 197 km^2) was approximately 18% of the 95% kernel size ($\bar{x}$ = 761 ± 653 km^2). MCP home range size averaged 585.3 ± 453.2 km^2. Only 45% of the locations within the 50% kernel were from the denning period (April-June).

Discussion

Den site selection appears strongest within 15 m of the den entrance but was also apparent (but less pronounced) within a 50-m radius of the den. We found dense cover (> 70% obscurity) near dens, and dens were often difficult to find and could rarely be seen from >20 meters. Previous studies in Montana (Matteson 1992), and Wisconsin and Minnesota (Unger 1999) did not find a significant cover difference between den and contrast locations. Matteson (1992) measured cover at 30.5 and 61 m, with cover values of 66.1 ± 27.3% and 91 ± 17.3%, respectively. In our opinion, Matteson measured cover at inappropriately long distances, which resulted in high horizontal cover

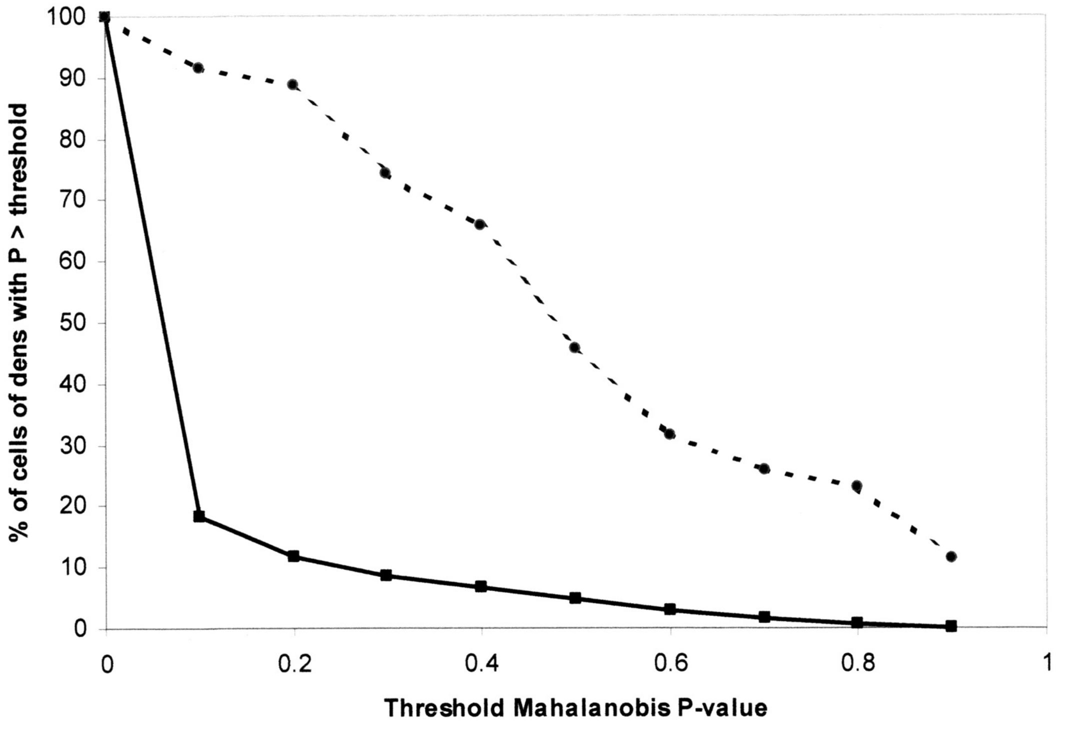

FIGURE 1. Percent of dens (dashed line) or cells (solid line) with Mahalanobis-*P* greater than or equal to threshold value for Wolf den site analysis in the northern Rocky Mountains, USA, 2003. Higher values along the x-axis indicate greater similarity to the mean vector of habitat measurements at Wolf dens.

values and reduced power to detect differences. Unger (1999) found average hiding cover at dens to be 70 ± 24% at 16 m, which is comparable to our results (72 ± 24%).

Canopy cover at den sites was considered unimportant by Matteson (1992) and Unger (1999). Both reported lower mean canopy cover values (43 ± 9% : Unger 1999; 19 ± 21% : Matteson 1992) than the 88 ± 22% we observed. These differences might be explained by the different collection methods. Matteson visually estimated canopy cover, whereas Unger used a point-intercept method. Nuttle (1997) suggested that point-intercept methods may not reflect an animal's perception of canopy cover.

Unger (1999) found steeper slopes at dens versus contrast sites. Although we did not identify slope as a selected den site attribute, our average slope of 15 degrees was similar to Unger's 14 degrees. Matteson (1992) found average slopes of 9 ± 11 degrees. Stephenson (1974*) found a much steeper average slope of 33 degrees in the Brooks Range of Alaska. Using elevation and slope measured in a GIS model, Oakleaf (2002) found core areas of pack home ranges in the northern Rocky Mountains at lower elevations with gentler slopes. Although we found that most dens were located within home range core areas, we found no significant correlation between den sites and elevation or slope.

Variables displaying significance at den site and den areas included Hiding Cover, Herbaceous Cover, and Rock Cover. Increased bare soil was significantly different at den areas but not at den sites. Denser canopy cover and small woody debris were significant at the site level, suggesting that Wolves respond to these two habitat variables immediately surrounding the den entrance. Denser canopy cover at the den entrance could suggest that Wolves select areas with more vertical protection, or this could be an artifact of selecting den sites near tree roots for increased structural integrity. Although small woody material may provide little structural defense from ground predators, it may provide visual obscurity.

Road and water GIS layers at 1:100 000 resolution were inaccurate when compared to field observations. In the field, we found most dens to be within 100 m of water, although GIS data revealed only three water sources within that distance. GIS layers depicted roads within 30 m of several dens where we found no roads in the field. These inaccuracies may have contributed to the lack of significant differences in variables derived from remotely-sensed data (Table 2). Hawbaker and Radeloff (2004) found that up to 50% of the roads in the landscape may be missing in digital road data. Their findings and our identification of "ghost" roads suggest that digital road data should be used with caution or field checked.

Eleven of 12 dens sampled were located within core areas (50% fixed kernel). Unger (1999) found that dens occurred more often in the central part of the MCP [minimum convex polygon], but Ciucci and Mech (1992) found Wolf dens located randomly throughout the MCP home ranges. Unger (1999) and Ciucci and Mech (1992) used different geometric methods to characterize den location as either being centrally or peripherally located in the MCP home range. Because the 50% fixed kernel estimator reflects the intensity of use in the home range, we believe it is a better predictor of denning areas. In our study only 45% of the locations within the 50% kernel were from the denning period (April-June). This suggests that Wolves use the denning area throughout the year.

Although Wolf den locations varied considerably with respect to elevation, slope, solar radiation, and coniferous forest cover, we identified several useful Mahalanobis distance models using these GIS data layers. Mahalanobis models with threshold P values of 0.10 to 0.20 are useful to managers, who can expect that about 90% of dens will occur within < 20% of the landscape. By combining Mahalanobis modeling with fixed kernel home ranges and core use areas, potential denning habitat can be predicted.

Conservation implications

Although some GIS-derived data layers appeared to be accurate (e.g., elevation, slope, aspect), other data layers (e.g., roads and water) were highly inaccurate compared with site-specific data measured in the field. As GIS use becomes more prevalent, managers should be aware of some of its potential limitations.

Mahalanobis models can help managers identify suitable den habitat. Of the models we developed, any with $P < 0.20$ would be useful to managers. Managers can use these models to evaluate the amount of potential denning habitat in Wolf-occupied areas or proposed reintroduction sites. Mahalanobis distances can be calculated at landscape, pack home range, or core use area scales.

When making land use decisions, managers are often provided with 100% MCPs for Wolf territories. Because territories in the Northern Rocky Mountains are large, averaging over 500 km^2, it may be difficult to meet management objectives. Smaller core areas based on 50% kernel estimator may be a better delineation for land use decisions because they show areas of more intense use. More than 90% of the dens we examined were located within the core use area of the pack, and these areas are being used throughout the year. Localized closures (e.g., one-kilometer diameter) during the denning period will decrease likelihood of premature abandonment of the den.

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