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Several mammals have adapted to harsh winter conditions by adopting hibernation strategies that enable them to survive periods of unfavourable environmental conditions. At northern latitudes, black and brown bears can be in a state of hibernation for up to seven months. As a result of this prolonged occupation of one small space, bears can be vulnerable to environmental and human caused disturbances. In this study, we developed a predictive model that identifies potential den habitat for black bears that can assist with management planning for industrial land development activities. We identified 40 dens (17 excavated in soil and 23 natural rock cavities) and used fine-scale information to determine how dens were positioned in forest stands. We found that bears denned in areas on mid to upper slope positions and that soil dens were located mainly in clay-loam soil complexes while rock cavity dens were either caves or cavities in boulder piles. Den location was distant from portions of the study area with relatively high road density. We then used resource selection functions to predict where bear dens might be located on the landscape. When applied to the GIS data, the averaged coefficients suggested that 3.1% of the study area had a high suitability ranking as den habitat while 9.1%, 14.6%, and 73.2% had mid, low, and limited suitability, respectively. In our study area, habitat for den sites is reasonably predictable and should be considered during the planning of industrial activities.

Several mammal species have adapted to harsh winter conditions by adopting hibernation strategies that enable them to survive periods of unfavourable environmental conditions (Carey et al. 2003). However, there is considerable variation in the behavioural and physiological adaptations of these species, ranging from deep hibernation to short periods of torpor (Carey et al. 2003). For example, some hibernators significantly reduce their heart rate and metabolism and maintain a body temperature within 1°C of ambient temperature while remaining non-responsive to external stimuli and awakening every few days to eat, drink, defecate, and urinate. Other hibernating species, such as American black bears *Ursus americanus* and brown bears *Ursus arctos*, reduce their body temperatures by 7–8°C while their heart and metabolic rates drop to 20–40% and 50–60% of normal levels, respectively (Hellgren 1998, Pelton 2003, Tøien et al. 2011). In this state, bears do not eat, drink, defecate or urinate during a period which can last up to seven months (Folk et al. 1976, Gaines 2003, Bridges et al. 2004). Regardless of the specific strategy, the evolution of this behaviour in the life history of mammals minimizes stress caused by a paucity of food.

Black and brown bears can be easily aroused during hibernation which may be a strategy allowing them to care for young that are born during winter (Pelton 2003). However, this adaptation predisposes bears to various forms of disturbance in their surroundings (Swenson et al. 1997). Linnell et al. (2000) suggested that bears were vulnerable to disturbance within 1000m of the den site, with these effects being particularly acute when disturbance occurs less than 200m from the den. Behavioural responses to disturbance can result in physiological stress, increased energetic costs or even mortality of young resulting from abandonment (Tietje and Ruff 1980, Oli et al. 1997, Swenson et al. 1997, Linnell et al. 2000, Baldwin and Bender 2008). Furthermore, anthropogenic activities can influence the distribution and fine-scale attributes of den sites, suggesting a reduction in den habitat where anthropogenic activities are wide-spread (Sahlén et al. 2011). Given the importance of dens for reproduction and survival of bears and the potential sensitivity of denning bears to disturbance, it is important that land managers understand how to preserve the integrity of habitat necessary for den sites (White et al. 2001, Baldwin and Bender 2008).

Black bears are habitat generalists and broadly distributed across North America leading to considerable potential for interaction between den selection and occupancy and industrial forestry and mining activities. While mining

activities occur year-round and are somewhat restricted to fixed areas, forestry activities are ubiquitous and in many areas occur primarily in winter affecting bears in hibernation. Currently, there is little guidance for natural resource professionals describing the habitat features that characterise den sites or the impacts of industrial development on the selection or use of dens by bears. In this project, we examined the location of bear dens in north-central British Columbia in an effort to consider these features when planning and mitigating industrial activities. Our objectives were to 1) identify and describe fine-scale attributes of black bear dens in managed sub-boreal forest environments, 2) use a species distribution model to correlate the location of known dens with stand and landscape-level variables (ecological and/or human disturbance), and 3) develop management recommendations that would help ensure the maintenance of den habitat and prevent disturbance of bears during the denning period.

Material and methods

Study area

Our study was located in the central interior of British Columbia, Canada. This region is currently experiencing unprecedented levels of forest harvesting as a result of a mountain pine beetle *Dendroctonus ponderosae* infestation while at the same time there has been a marked increase in mining exploration and development. Specifically, our study area is located in the John Prince Research Forest (JPRF; 54°40′14″N; 124°25′13″W) which is a working forest that is co-managed by the Univ. of Northern British Columbia and the Tl'azt'en Nation (a local indigenous community) in central British Columbia. The JPRF is a 165 km²-area of forested landscape characterized by rolling terrain with low mountains (700 m to 1500 m a.s.l) within the Sub-Boreal Spruce biogeoclimatic zone (Delong et al. 1993). The dominant tree species are trembling aspen *Populus tremuloides* subalpine fir *Abies lasiocarpa*, Douglas-fir *Pseudotsuga menziesii*, lodgepole pine *Pinus contorta* and white spruce *Picea glauca*. The geology of the area is represented by two major sources of bedrock, limestone and ultra-mafic, with much of the area being covered by glacial till. The soils of the JPRF are shallow and composed mainly of luvisols (high clay content) with limited amounts of brunisols (well drained). American black bears are a common part of the local fauna (257/1000 km²), while brown bears occur at much lower densities (17/1000 km²) in the area (Mowat et al. 2005).

Den survey

From 2003 to 2008, we located 40 dens that were previously occupied by bears. These dens were primarily black bear dens (as determined by field signs such as tracks or hair) however some were undetermined and could have been brown bear dens. Dens were located using a variety of methods as part of ongoing ecological monitoring programs on the JPRF. We used random reconnaissance surveys, traditional aboriginal knowledge, back-tracking of bears in snow during spring, and forest worker reports. All field personnel working in the study area were trained to identify and record locations of dens (or suspected dens). These sites were then reported to project staff that followed up with detailed den and ecological descriptions. We established timber cruise plots for a subset of dens (n = 21) to determine merchantable timber volume per hectare in the vicinity of dens (British Columbia Ministry of Forests 2001).

Statistical representation of den selection

We used resource selection functions (RSF) to quantify the influence of topography, vegetation, and human disturbance on the distribution of den sites in the JPRF (Mace et al. 1996, Seip et al. 2007). Empirically based, RSFs allowed us to identify the strength of animal-resource (i.e. habitat) relationships where strong selection or suitability is indicated by high RSF values. Importance of resources is contingent on selection being related to the life history and fitness requirements of the study species and ultimately demography of the population (Johnson and Seip 2008). A RSF produces a series of coefficients that quantify the strength of avoidance or selection for specific habitat covariates. When considered additively (Eq. 1), the series of coefficients indicate the relative probability of a bear selecting any location from across the study area as a den site (Johnson et al. 2006).

$$w(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_i) \tag{1}$$

We used logistic regression to estimate coefficients for the RSF model (Eq. 1). We contrasted den sites with an equal number of randomly selected non-den locations. The random sites were selected from an area representing the 100% minimum convex polygon of the known den locations. Although RSF is robust to sample contamination, the relatively low density and permanence of known dens suggest that it is unlikely that the random sites were false absences (Johnson et al. 2006).

Model selection, fit, and prediction

We developed a series of RSF models that served as ecologically plausible hypotheses for explaining the distribution of bear dens across the JPRF. When identifying these hypotheses, we drew guidance from the literature and our understanding of the ecology of the study area. Our working premise was that den selection was a function of bears responding to three sets of functional variables: soil and topography, forest structure, and human disturbance. Variables for slope, aspect, elevation and soil productivity allowed us to test site factors that might influence the excavation or formation of dens. For this set of models, we also hypothesised that bears would locate dens adjacent to a source of water. Forest structure was represented by tree species, age, size, and canopy closure. These variables are correlated with forest management decisions (JPRF unpubl. report) and may influence habitat selection of bears. Human activities may cause bears to avoid suitable denning habitat. Here, we considered disturbance effects as the distance from trails and roads as well as broader-scale avoidance responses associated with the density of roads across the study area. For these models, we included tree species and elevation, as we hypothesised that ecological site factors would co-vary with disturbance effects.

Table 1. Independent variables used for resource selection function models describing the distribution of black bear dens in the John Prince Research Forest, central British Columbia, Canada. All measures are representative of the GIS polygon or pixel in which the den was located.

Variable name	Coding/levels	Description
Soil nutrient	categorical:4	available nutrient supply within soil for plant growth: very poor, poor, medium, rich
Site index	continuous	site productivity for tree growth represented as the height in metres of dominant tree type at age 50
Slope	continuous	slope in degrees at den location
Aspect	continuous	southerly aspect of den as degrees from north
Elevation	continuous	elevation above sea level at den
Distance to water	continuous	distance from nearest river or lake
Crown closure	continuous	percentage of ground area covered by the vertically projected crowns of the tree cover
Tree species	categorical:5	dominant tree species: deciduous (trembling aspen *Populus tremuloides*/paper birch *Betula papyrifera*), subalpine fir *Abies lasiocarpa*, Douglas-fir *Pseudotsuga menziesii*, lodgepole pine *Pinus contorta*, and white spruce *Picea glauca*
Basal area	continuous	total cross sectional area of all living trees; index of volume of standing timber
Stand age	continuous	average age of dominant and codominant trees
Distance to road	continuous	straight line distance from den to nearest road passable by highway vehicle
Distance to trail	continuous	straight line distance from den to nearest trail
Road density	continuous	density of road segments (25×25-m pixel) within 1×1 km moving window

The final RSF model was intended to serve as a predictive tool for identifying potential den habitat and correspondingly guiding industrial development including forestry and mining. Thus, we fit a fourth set of models that included those variables found within the most parsimonious of the sets representing soil and topography, forest structure, and human disturbance. We considered those models and corresponding results as a post hoc analysis focused on prediction, not the exploration of a priori hypotheses.

We generated or collected 13 spatial variables for parameterising the RSF models (Table 1). Ecological covariates representing soil productivity and forest composition, canopy closure, and mean tree age were extracted from the provincial Vegetation Resources Inventory (<www.for.gov.bc.ca/hts/vri/index.html>). We derived slope, aspect, and elevation from a digital elevation model (25×25-m pixel resolution) of the study area. We used vector GIS data developed by provincial agencies or the JPRF to represent roads, trails, and water bodies. We used the linear road data to generate an image of road density for the study area within a 1×1-km moving window (Table 1). Categorical variables were represented using deviation coding and distance measures were converted from metre to hectometre for ease of interpretation.

We used the Akaike information criterion difference (ΔAIC_c) for small samples and weights ($AIC_c w$) to select the most parsimonious model from each functional category (Anderson et al. 2000). We used the receiver operating characteristic (ROC) to assess the classification accuracy of the RSF models (Pearce and Ferrier 2000). This is a conservative estimate because we assume that all random locations are absent of den sites (Boyce et al. 2002). We had insufficient sample size to withhold a percentage of the observations that would allow us to generate an independent test of classification accuracy. Thus, we used a one-fold cross validation routine to withhold each record sequentially from the model building process and then calculate the probability of that withheld record being a den site. We used these independent probabilities to generate the ROC test. We considered a model with an 'area under the curve' (AUC) score of 0.7 to 0.9 to be a

'useful application' and a model with a score > 0.9 as 'highly accurate' (Boyce et al. 2002).

We used 95% confidence intervals to assess the strength of effect of each predictor covariate on the dependent variable. Poor power and inconclusive statistical inference is expected from covariates with confidence intervals that approach or overlap 0. We used tolerance scores to assess variables within each model for excessive collinearity (Menard 1995).

Predicting the distribution of suitable den habitat

The location of existing, potential or future den sites is incorporated within timber supply calculations for the JPRF. We used the set of RSF models to predict the spatial distribution of habitat that is suitable for den establishment by black bears. We populated Eq. 1 with the averaged coefficients ($\beta_1...\beta_i$) from the RSF models and applied that equation to the respective GIS data ($x_1...x_i$). Model averaging (Anderson et al. 2000) allowed us to represent the uncertainty inherent in the model selection process. We averaged those models that constituted 95% of the AIC weights across the full suite of models within the soil and topography, forest structure and human disturbance subsets. Following the application of the averaged model to the study area, we grouped the continuous range of predicted RSF scores into 4 habitat classes representing a low to a high relative probability of selection of a den site. We used the quartiles calculated from the predicted RSF scores (w) for the observed den and random site data to define class break points.

Results

Of the 40 dens surveyed, 17 (42.5%) were excavated from soil material and 23 (57.5%) were located in rock cavities. We located only one tree den in our study area, which we excluded from our analysis. Dens were located on mid to upper slope positions 88.2% and 86.9 % of the time for excavated and rock cavity dens, respectively. We found that excavated dens were almost exclusively found in a variety of clay-loam soils with tree roots or boulders providing

Table 2. Percent frequency of dens relative to fine-scale habitat variables at a subset of excavated (n = 8) and rock cavity (n = 13) bear den sites in the John Prince Research Forest, central British Columbia, Canada.

	Den type	
Habitat variable	Excavated	Rock cavity
Slope position		
upper slope	35.3	21.7
mid slope	52.9	65.2
lower slope	11.8	13.1
Substrate		
bedrock	0	73.9
boulders	0	26.1
sandy clay loam	29.4	0
clay loam	35.3	0
silty clay loam	29.4	0
organic	5.9	0
Structure		
tree roots	76.5	0
boulder pile	0	26.1
under boulder	23.5	0
cave	0	73.9

structural support while rock cavity dens occurred in caves in bedrock with some being cavities created by boulder piles (Table 2). In addition, excavated soil dens were located in forest stands that had significantly more timber volume per hectare than rock cavity dens ($t(19) = 2.179$, p = 0.02).

Across the total area of occupancy, defined by the minimum convex polygon of den sites, the 40 dens resulted in a minimum density of 0.22 dens km^{-2}. We used the 40 known den sites and an equal number of random locations to fit 21 RSF models. The models constructed from covariates representative of soil and topographic conditions were the most predictive of the three a priori sets of models (Table 3). The most parsimonious model within that functional group consisted of covariates for slope and aspect; however, an AIC$_c w_i$ of 0.61 suggested some model selection uncertainty. Bears selected for steeper slopes ($\beta = 0.158$, 95% CI = 0.079–0.238) and demonstrated indeterminate selection for sites with southeast facing aspects ($\beta = 0.008$, 95% CI = –0.002–0.017). This model had good predictive accuracy (AUC$_i$ = 0.83, SE = 0.05).

For the set of models testing human disturbance as an influencing factor on den location, the model consisting of road density, tree species, and elevation was the most parsimonious (AIC$_c w_i$ = 0.75) and predictive (AUC$_i$ = 0.65, 0.06). There was some evidence that bears avoided areas with greater road density ($\beta = –0.731$, 95% CI = –1.543–0.081) and selected for den sites at relatively higher elevations ($\beta = 0.810$, 95% CI = 0.304–1.316). When considering forest structure, the most parsimonious model consisted of

Table 3. Global AIC$_c$ scores, as well as differences in AIC$_c$ scores (Δ) and AIC$_c$ weights (w) within a model set for resource selection function models representing the location of black bear dens in the John Prince Research Forest, central British Columbia, Canada. 'Area under the curve' (AUC) and standard error (SE) for the receiver operating characteristic represents predictive accuracy of each model.

| Model	K_i	AIC_{ci}	$AIC_{c\Delta i}$	$AIC_c w_i$	AUC_i (SE)
Soil–topography					
slope + aspect	3	87.4	0.0	0.61	0.83 (0.05)
slope + aspect + elevation	4	89.5	2.1	0.21	0.83 (0.05)
soil nutrients + site index + slope	6	91.1	3.8	0.09	0.84 (0.06)
slope + aspect + elevation + distance water	5	91.4	4.0	0.08	0.83 (0.05)
soil nutrients + site index + slope + aspect + elevation + dist water	9	96.7	9.4	0.01	0.85 (0.06)
soil nutrients + site index	5	100.3	13.0	<0.01	0.78 (0.06)
elevation	2	105.9	18.5	<0.01	0.68 (0.06)
Forest structure					
crown closure + basal area + stand age	4	105.8	0.0	0.91	0.68 (0.06)
crown closure + basal area + tree sp + stand age	9	111.9	6.2	0.04	0.63 (0.06)
stand age	2	112.3	6.6	0.03	0.58 (0.07)
tree sp	6	113.5	7.8	0.02	0.50 (0.07)
Disturbance					
road density + tree species + elevation	8	108.5	0.0	0.75	0.65 (0.06)
distance road + tree species + elevation	8	112.4	3.8	0.11	0.62 (0.06)
distance trail + tree species + elevation	8	112.5	3.9	0.11	0.60 (0.06)
distance road + distance trail + tree sp + elevation	9	114.7	6.2	0.03	0.60 (0.06)
Post hoc model combination					
road density + slope + aspect	4	83.7	0.0	0.55	0.82 (0.05)
road density + slope + aspect + elevation	5	84.6	0.9	0.34	0.83 (0.05)
slope + aspect + crown closure + basal area + age	6	88.3	4.6	0.06	0.79 (0.05)
crown closure + slope + aspect	4	88.7	5.0	0.05	0.80 (0.05)
road density + slope + aspect + elevation + tree sp	9	93.7	10.0	<0.01	0.79 (0.05)
tree sp + slope + aspect	7	94.5	10.8	<0.01	0.77 (0.05)
Total model ranking (95% AIC$_c$w)					
road density + slope + aspect	4	83.7	0.0	0.45	0.82 (0.05)
road density + slope + aspect + elevation	5	84.6	0.9	0.30	0.83 (0.05)
slope + aspect	3	87.4	3.6	0.08	0.83 (0.05)
slope + aspect + crown closure + basal area + age	6	88.3	4.6	0.05	0.79 (0.05)
crown closure + slope + aspect	4	88.7	5.0	0.04	0.80 (0.05)
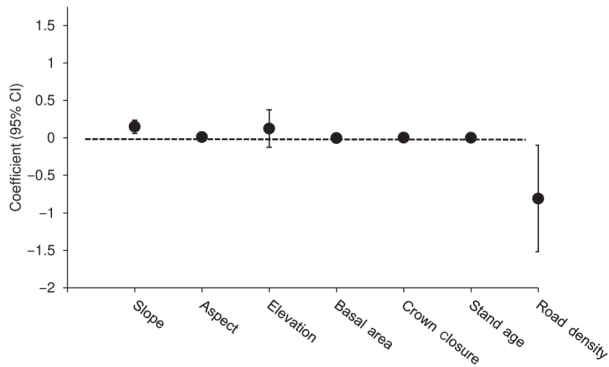
Figure 1. Model averaged coefficients and 95% confidence intervals illustrating selection of site attributes by black bears at dens in the John Prince Research Forest, central British Columbia, Canada. Weighted averages and variances were corrected for model selection uncertainty using the top 95% of AICw (Table 2).

crown closure, basal area, and stand age (AIC$_c w_i$ = 0.91); that model was the most predictive of the set (AUC$_i$ = 0.68, SE = 0.06). Based on this evidence, bears selected for sites with relatively older forest stands (β = 0.021, 95% CI = 0.007–0.035), with lower basal area (β = −0.104, 95% CI = −0.174– −0.034), and inconclusively, greater crown closure (β = 0.035, 95% CI = −0.007–0.076).

The most parsimonious and predictive models were contained in the post hoc set. Here, a model consisting of road density, slope, and aspect resulted in an AIC$_c w_i$ of 0.55, but was followed closely by a slightly more complex model that also contained a covariate for elevation (AIC$_c w_i$ = 0.34). These two top ranked models were among the most predictive of the full set of models considered (Table 3).

When ranking the full suite of models, the top 95% of weights was represented by five models (total AIC$_c w$ = 0.95). After model averaging, coefficient values suggested that bears selected den sites at steep, high-elevation, southeast facing sites with low road density and in relatively older forest stands with low basal area and greater crown closure. When considering model selection uncertainty, however, only the model averaged coefficient for slope ($\overline{X}\beta$ = 0.148, 95% CI$_{corrected}$ = 0.060–0.236) and road density ($\overline{X}\beta$ = −0.807, 95% CI$_{corrected}$ = −1.517– −0.098) had a confidence interval that did not overlap 0 (Fig. 1). When applied to the GIS data, the averaged coefficients suggested that 3.1% of the study area had a high suitability ranking as den habitat while 9.1%, 14.6% and 73.2% had mid, low, and limited suitability, respectively (Fig. 2).

Discussion

Bears in our study area chose a mix of excavated and rock cavity dens which is consistent with studies from other areas in the northern part of black bear range (Schwartz et al. 1987, Linnell et al. 2000). Although soils in the JPRF are predominantly high in clay content we found that black bears established soil dens in better drained clay-loam soils on mid to upper slope positions perhaps suggesting some selectivity as reported by Beecham et al. (1983). However, other authors suggested that the use of various soil types

for den sites is opportunistic (Lindzey and Meslow 1976, Schwartz et al. 1987). We also observed that soil dens were almost always constructed under tree roots or boulders which provided extra stability and longevity. Rock cavity dens were also found primarily on mid to upper slope positions similar to dens investigated by Schwartz et al. (1987) in Alaska. Tree dens are common in many areas throughout the southern distribution of black bear range (Wathen et al. 1986, White et al. 2001, Ryan and Vaughan 2004) and coastal areas of British Columbia (Davis 1996). However, few trees in our study area are of sufficient size (> 90 cm at DBH) to facilitate a den excavation.

The most parsimonious a priori model from the RSF analyses consisted of variables for slope and aspect. Other models including variables for elevation, soil nutrients, site index and distance to water had larger AIC$_c$ scores, but they were equally as predictive as the top ranked model. With the exception of road density, covariates for human disturbance had relatively less influence on den selection compared to topographical variables. This suggests that bears may not strongly avoid individual roads or trails in our study area, but instead larger areas with a high density of human activities. Goldstein et al. (2010) reported qualitatively similar results for selection of dens by brown bear in Alaska. Alternatively, Petram et al. (2004) did not find a strong correlation between the location of brown bear dens in Slovenia and human activities. Such differences in results might be explained by variation in human activity, not simply the presence of anthropogenic features. Roads and trails across the JPRF have little traffic during winter (majority of roads are not plowed). An increase in human activity, as a result of the escalation of mining and forestry activities, might affect the use of existing dens or selection of new sites by bears (Sahlén et al. 2011).

Covariates describing forest structure had relatively little influence on den site selection. Aside from growing substrate, our data suggest a weak correlation between forest attributes that influence harvesting prescriptions and the selection of dens by bears. Forest managers should therefore be aware that substrate, slope and aspect influence den sites and manage accordingly for dens across a range of productive and non-productive forest types.

We used timber volume per hectare (m^3 ha^{-1}) as a surrogate for the associated economic value of removing den habitat from areas of operational forestry. Soil excavations occurred in areas with more productive growing conditions and higher timber volumes when compared to rock cavity dens on thinner soils. Considering this, and the fact that the majority of timber harvesting in our study area occurs during the denning period, we concluded that soil dens are more vulnerable to industrial forestry activities. Conversely, rock cavities were situated in relatively poor growing sites with less timber volume, albeit mining exploration and development could threaten dens or disturb hibernating bears. Furthermore, rock cavities are more permanent on the landscape and possibly have higher conservation value due to their reuse by multiple generations of bears (Schwartz et al. 1987). In addition, in areas where black and grizzly bears coexist (such as our study area), rock cavity dens may provide black bears with security from in-den predation by larger grizzly bears.
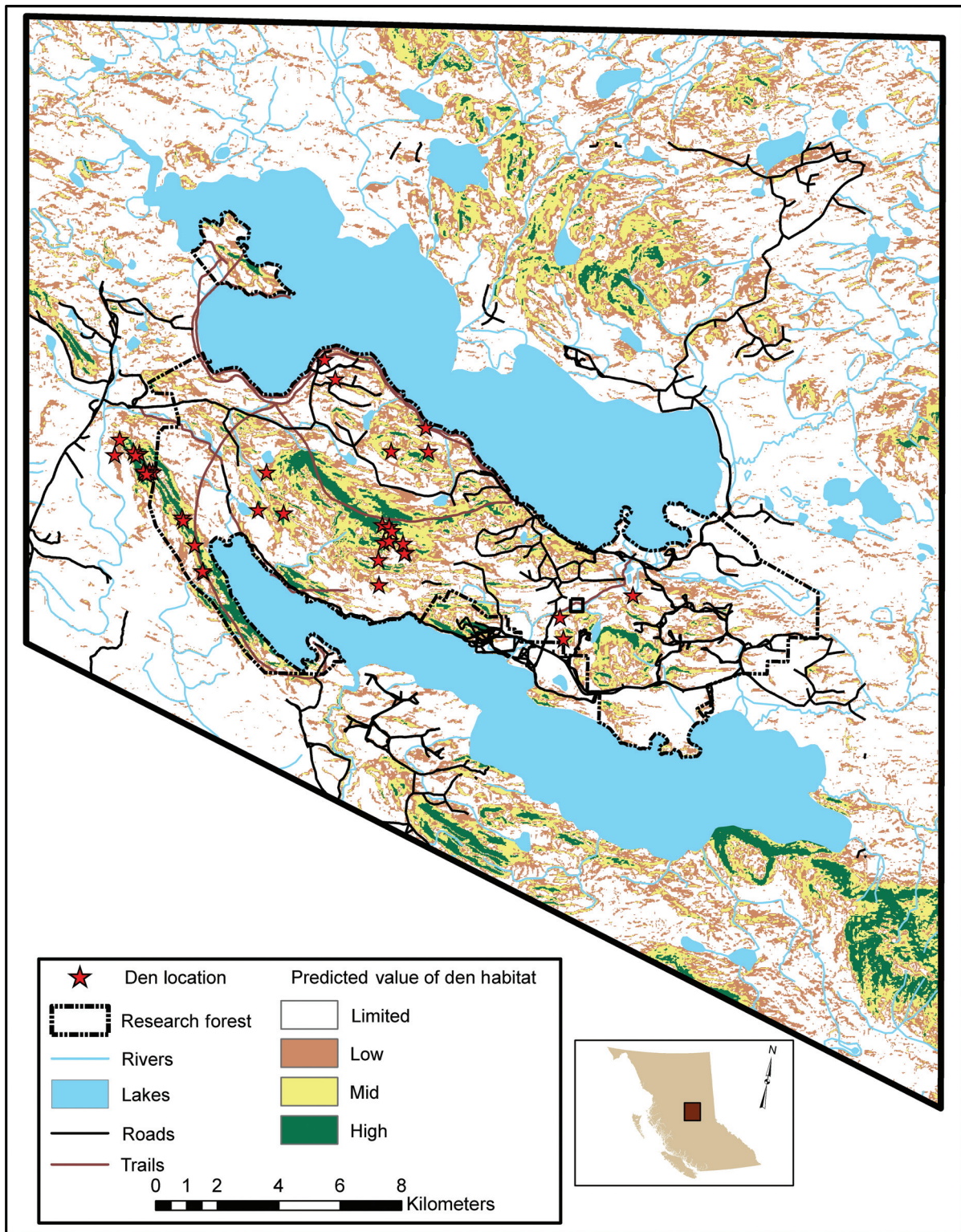
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Figure 2. Spatial extrapolation of averaged coefficients from top ranked RSF models (Table 3, Fig. 1) predicting high-quality den habitat for black bears across the John Prince Research Forest, central British Columbia, Canada.

Management implications

Across British Columbia and other jurisdictions, black bears are sought after by resident and guided hunters and have important cultural and subsistence values for First Nations peoples. Furthermore, as an apex carnivore/ omnivore, black bears play an important role in forested ecosystems; such species are facing increasing risks from anthropogenic activities (Estes et al. 2011). While no specific legal directions are in place for management of denning habitat, regulatory agencies do require den assessments as part of development activities in certain cases and

best management practices do exist for active den sites. As a result, many management agencies and industrial licensees have best practice guidance for active dens, typically in the form of some minimum no-disturbance buffer (e.g. 50-m radius) around den sites. For our study area, natural resource planners from the Tl'azt'en Nation use information describing the habitats of key wildlife species, such as black and grizzly bear, to identify important areas throughout their traditional territory and guide industry when planning development.

In the JPRF, forestry is the major potential disturbance factor for denning bears. However, there is a noticeable increase in active mining exploration surrounding the study area, and winter recreation (e.g. snowmobiling) can serve as a significant source of disturbance (Goldstein et al. 2010). The JPRF uses the results of this study at two scales in the forest management planning process. The outputs of the RSF models are integrated in landscape-level management plans to identify areas that have a relatively high likelihood of supporting current or future dens and that require limits on forest harvesting or development restrictions. For example, restrictions have been implemented on the volume of wood harvested from areas with natural cavity dens and concentrations of excavated dens. At a finer scale, the JPRF has restricted industrial activities and implemented management buffers in areas with active dens or high potential denning areas. Before approving harvesting plans, site assessments are conducted of mid to upper slopes with well drained soils that might contain den sites. While we acknowledge that dens may not be yet excavated for the current year, evidence of older dens can suggest that conditions for den construction are suitable.

Despite the potential vulnerability of bears to disturbance during hibernation, there are few published guidelines for managing anthropogenic activities during the denning season. Natural resource professionals can directly manage disturbance and human activities directly adjacent to known dens. However, known dens are likely only a subset of the total dens across the managed landscape. Den sites are strongly correlated with some environmental attributes and those attributes, as represented in predictive maps of den habitat, should be considered during the approval and mitigation of industrial projects. Our results, in addition to those of others (Petram et al. 2004, Elfström et al. 2008, Goldstein et al. 2010, Sahlén et al. 2011, Waller et al. 2013) suggest that it is possible to evaluate potential impacts of industrial activities on den use and associated habitats at the scale of the landscape and stand.

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